*Materials Engineering in Product Design + Manufacture*

# Materials & Methods





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*Materials Engineering in Product Design & Manufacture*

# Materials & Methods.

**JULY 1954** **VOL. 40, NO. 1**

## FEATURE ARTICLES



## MATERIALS & METHODS MANUAL NO. 106



## ENGINEERING FILE FACTS



## DEPARTMENTS



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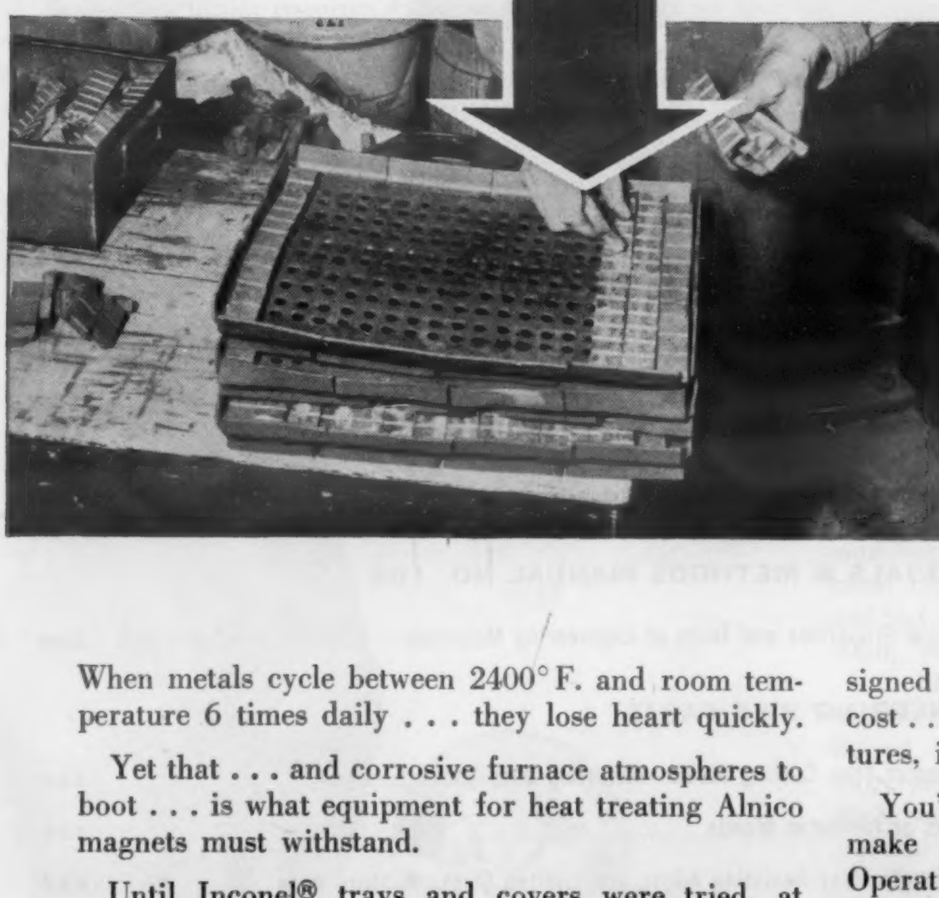
**At General Magnetic Corporation,** 10001 Erwin Street, Detroit, Michigan, magnets are brought up to heat, 2400°F. in one hour, soaked 20 minutes, then cooled in 10 minutes to 300-400°F. They ride in Inconel trays with Inconel covers to protect them against direct heat.

# UP to 2400° F.

# DOWN to "Handling cool" 6 times daily

## Yet Inconel trays and covers serve a full six months treating Alnico magnets



**After discharge** trays are allowed to cool to handling temperature, then reloaded 6 to 7 times daily. Expansion slots help reduce stresses created by cycling between temperature extremes. Design and fabrication by Misco Fabricators, 1999 Guion St., Detroit 7, Michigan.

When metals cycle between 2400°F. and room temperature 6 times daily . . . they lose heart quickly.

Yet that . . . and corrosive furnace atmospheres to boot . . . is what equipment for heat treating Alnico magnets must withstand.

Until Inconel® trays and covers were tried, at General Magnetic Corporation, no material proved satisfactory. Now, with Inconel, six months or more of service is obtained.

These trays and covers were made by Misco Fabricators, who specialize in heat treating equipment. They use Inconel extensively where, as in this case, requirements are rigorous.

Inconel retains good strength at high temperatures. It also shows little or no effect from carburizing or nitriding furnace atmospheres. Then, too, it is readily fabricated and repaired.

These are the reasons you can expect a well designed piece of Inconel equipment to show low overall cost . . . and give little trouble. At very high temperatures, it often is the only practical material to use.

You'll find many suggestions on practical ways to make Inconel heat treating equipment in "Keep Operating Costs Down . . . When Temperatures Go Up." If you would like a free copy of this booklet, write:

**The INTERNATIONAL NICKEL COMPANY, Inc.**
67 Wall Street New York 5, N. Y.

**Inconel Incoloy . . .**

INCO TRADE MARK

**Nickel Alloys**
**for long life at high temperatures**

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# The Materials Outlook

**UPGRADING STAINLESS**

Savings in expensive and critical elements needed in superalloys may be possible in the future as a result of experimental work now being done on upgrading nickel-chromium stainless steels. Additions of titanium and boron have increased high-temperature strength sufficiently so that the new materials may be able to replace superalloys in many present applications up to 1500 F.

**PLASTICS FOR TOOLING**

Plastics tooling engineers are asking for materials with better heat distortion characteristics. One answer may be a new phenolic resin just developed. In the past it has been difficult to achieve a good bond between phenolics and glass fiber, but laminates of unusually high strength are claimed with the new resin. Another answer may be a new epoxy resin, still in the developmental stage, which is reported to have a heat distortion temperature of about 350 F.

**FASTER NICKEL PLATING**

Faster nickel plating has been made possible with improvement of the sulfamate process commonly used to apply heavy coatings. A new commercial bath plates up to 7 mils per hr compared to the usual maximum rate of 4 mils per hr. Resulting coatings are claimed to be harder, yet less brittle, than conventional sulfamate coatings.

**FORMING PLASTIC SHEET**

There has been a tremendous growth of interest in vacuum forming of plastics recently. Growing acceptance of large plastics moldings, improved sheet materials and new automatic short-cycle machines are responsible. The trend is so strong that some people in the industry are convinced that the process has been oversold. They point to a number of recent applications where another method, such as plug-and-ring forming, would have been cheaper.

**NEW STOCKPILE FOR METALS**

The Government plans to buy lead and zinc as part of a new "long-term" stockpiling program. Ultimately, many other metals and minerals may be added, but the immediate purpose of the program is to help the domestic mining industry which has been faced with a continuing drop in demand and in prices.

**NEW STANDARD LAMINATE MATERIAL**

A glass mat bonded with phenolic resin is reported to be under development as a possible standard material for high pressure laminates.

*(Continued on page 4)*

# The Materials Outlook *(continued)*

**TITANIUM**

There seems to be no unanimous opinion on the quality and uniformity of titanium and titanium alloys now available. One company says it's "not satisfied with the quality", but an engine manufacturer says quality is "acceptable" and plans to use sheet, forgings and extrusions in a new engine. Everyone agrees that uniformity is improving . . . Much work is being done on getting closer-tolerance forgings and extrusions of titanium to eliminate machining . . . In one plant, titanium is being clad with aluminum to protect its surface against contamination during forming operations.

**VINYL FOAM SHEET**

Foamed vinyl plastisols are threatening to replace foam and sponge rubber for many applications. Latest news is that foamed vinyl sheet will be on the market in quantity shortly. The sheet will be available in widths up to 54 in., thicknesses up to 4½ in., and in various colors.

**ALUMINUM-PIGMENTED NEOPRENE COATINGS**

An aluminum-pigmented neoprene coating for protecting metals in severely corrosive atmospheres is now available. It combines the functional advantages of neoprene with the attractive appearance of aluminum and can be tinted to provide a wide range of metallic colors.

**CLOSE-TOLERANCE NYLON MOLDING**

Tolerances for plastic moldings are the subject of many an argument, but there's little doubt that a current job involving a thin ½-in. long rod of glass-filled nylon represents a notable achievement. Reject rate is 60%, but here are the dimensions: $0.109\frac{0.0005}{0.0000}$ in. o.d.; a long hole at one end measuring $0.060\frac{0.001}{0.000}$ in.; and a smaller connecting hole at the other end which must be concentric with the larger hole within 0.0005 in. total indicator reading.

**FLUTED ALUMINUM TUBING**

Fluted aluminum tubing is now available in outside diameters ranging from ⅜ to 1 in. and wall thicknesses from 0.050 to 0.062 in. Properties: 32,000 psi tensile strength, 25,000 psi yield strength and 8% elongation. Expected uses: furniture, clothes poles, ladder rungs, etc.

**HIGH-TEAR STRENGTH ELASTOMER**

A new elastomer consisting of a combination of Teflon and a silicone is claimed to offer the thermal properties of silicones with improved tear strength and oil resistance. The material is said to have tear strength up to 210 lb/in. and to retain its flexibility from −120 to 600 F.

**STAMPING VINYL**

A method of forming rigid vinyl sheet on conventional metal stamping machinery has been developed. The sheet is fed from reels under a bank of strip heaters where its temperature is raised to about 270 F. A clutch arrangement permits the sheet to be fed intermittently to the press. Cycle time is 10 sec.

# Men of Materials...

*their views*
*on development*
*and utilization*
*of engineering materials*
*in industry*

**Francis L. LaQue**

*Vice President and Manager*
*Development and Research Div.*
*The International Nickel Co., Inc.*

Corrosion costs industry and the public more in lost time, equipment and money than any other type of wear or destruction. Francis L. LaQue of International Nickel Company has devoted broad knowledge of materials, leadership and organizational ability, and a large amount of good common sense oriented around scientific method to the study of corrosion and ways to combat it. He devotes a great deal of time to spreading the gospel of the corrosion engineer. His work has been widely published in society publications and he is a well known speaker to many technical and scientific organizations. He is editor of the Bulletin of The Sea Horse Institute, is a Past President of the National Association of Corrosion Engineers, for a number of years has held committee chairmanships in the ASTM, and is a member of the Corrosion Advisory Committee of the National Research Council.

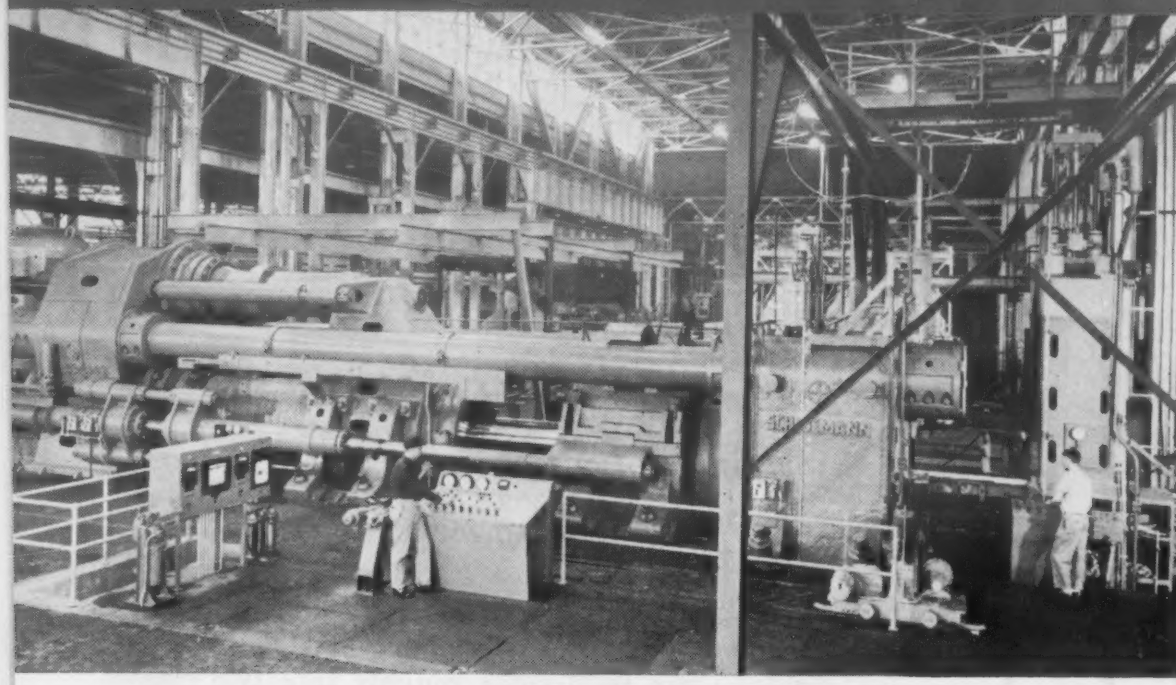
"Corrosion problems can be divided roughly into two classes—those of general interest and those of special interest. A problem of general interest may be defined as one that is related to a corrosive environment that may be encountered by a great many people, such as the atmosphere, or to a material that is in common use in many environments. A problem of particular interest is one that may be encountered in the extreme case in only a single instance. In making this distinction we are fully aware that every *practical* corrosion problem is a specific one.

The ASTM investigations of corrosion have been confined to environments of general interest, yet considerable attention has been devoted to tests that may be of special interest. Of necessity, the conditions under which such tests are carried out have had to be standardized rather rigidly . . . and it follows that results of such tests apply to very limited and rarely encountered conditions. Failure to recognize this fact has resulted in misapplications of tests, failures and disappointments due not to deficiencies in tests but to abuses in the use of them.

Recognition of test limitations and the basis for them in the direct application of test results does not destroy the value of the results we have. Instead, it points the way to their profitable use not only in selecting a suitable material or protecting one in a proper way, but also points the way to properly designing or arranging the materials in use so they will have the best possible chance of resisting the corrosive action they encounter.

Because of the broad range of corrosion problems, corrosion engineering applies special knowledge that carries the name of the several other branches of engineering. Besides a knowledge of corrosion itself, a corrosion engineer must have a knowledge of materials, characteristics of chemicals, fabrication techniques, availability of materials and proficiency in planning and executing test programs. If given the opportunity and proper time, a corrosion engineer should be able to guide design and specify materials and how they should be fabricated so that costly corrosion failures should be as rare as catastrophic failures in structural engineering.

While corrosion has nothing but negative aspects from most points of view; money spent to control corrosion is one of the most profitable investments that can be made."



**In production.** The 14,000-ton Schloemann extrusion press is the first of the units ordered under the U.S. Air Force Heavy press program to begin production.

**Extrusion cylinders** for the press weigh up to 15 tons each.

# 14,000-Ton Press Starts Production

## *First Completed Unit for Heavy Press Program*

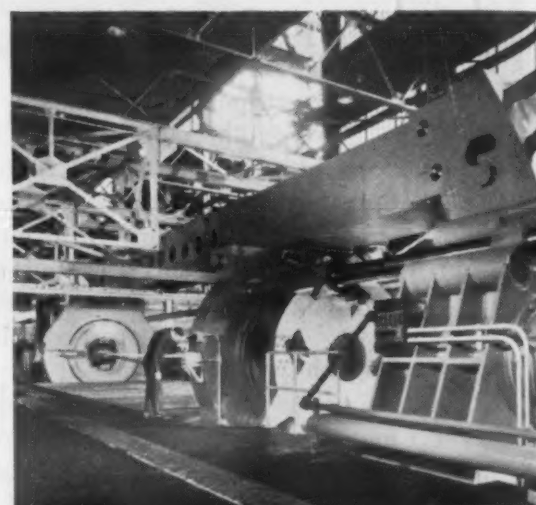
The big squeeze is on. After more than a year of debugging, realigning, and shaking down, the first of the Heavy Press Program's giant new extrusion presses is ready for production.

The 14,000-ton press can extrude sections of aluminum weighing as much as 2500 lb up to 110 ft long. At the 110-ft length, the maximum weight per pound of extrusions has been increased by the new press from 5.4 lb per foot to 22.7 lb per foot, (representing a cross sectional area of 19 sq in.). The practical maximum circumscribing circle for shapes has increased from the previous maximum of 13 in. to 23 in. The equipment can handle extrusions with cross sectional areas up to 60 sq inches in tough 75S alloy.

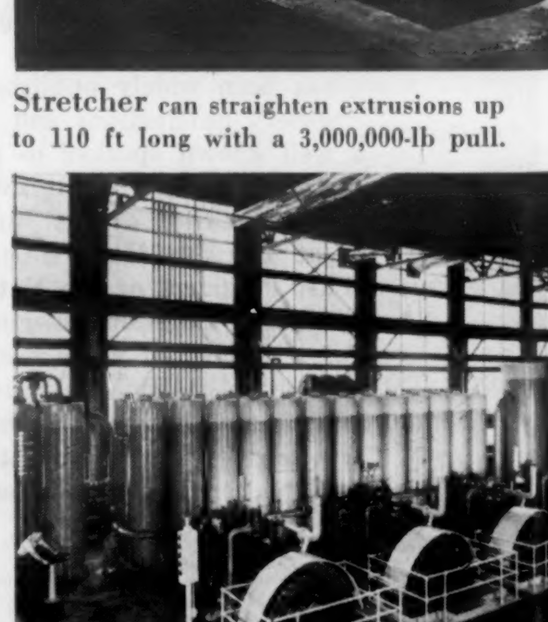
Initially, the presses will produce aircraft components such as wing spars and spar caps. Later, large extruded shapes will be available to manufacturers of transportation equipment and other civilian uses. Pipes up to a diameter of 20 in. can be fabricated for use in pipe lines.

Ancillary equipment for the big Schloemann unit is as impressive as the press itself. Ingots up to 20 by 76 in. are heated in large induction furnaces and fed automatically to the press. A 180-ft long stretcher has been installed to straighten and stress relieve full length extruded sections at stretching tensions up to 3,000,000 lb. Heat treating furnaces—one vertical and one horizontal—are capable of heat treating and quenching full length 110-ft pieces. A 96-in. circular saw cuts the extrusion to required lengths after heat treatment and stress relieving operations are now completed.

The Lafayette, Indiana works of the Aluminum Company of America is operating the press for the Air Force Heavy Press program.



**Stretcher** can straighten extrusions up to 110 ft long with a 3,000,000-lb pull.



**Pumps and accumulators** for the 14,000-ton press hydraulic system.

## Tougher, Stronger Titanium Alloy

Several commercial producers are melting production sized ingots of a tougher, stronger titanium alloy with properties comparable to the high strength steels used in weapons and armor plate. Armour Research Foundation, under contract to Watertown Arsenal Laboratory, developed the new alloy. Army tests at the Watertown Materials Testing Laboratory indicate that the new titanium based material overcomes many of the disadvantages, such as lack of ductility at high strength, which have limited the use of titanium in many ordnance applications.

Like other titanium based alloys, the new 6% aluminum, 4% vanadium material is 45% lighter than steel, has good corrosion resistance.

Unusual ductility at high strength levels differentiates the new material from present alloys. Heat treated to a tensile strength of 190,000 psi, it maintains a ductility of 14% elongation and 45% reduction in area. The notch toughness at this strength also remains unusually high as indicated by Charpy impact values of 11 ft lb at —40 F. For even higher toughness requirements, a different heat treatment gives 32 ft lb V notch Charpy impact energy at a tensile strength of 147,000 psi with 18% elongation and 56% reduction in area.

The properties of the new alloy compare very well with the martensitic stainless steels. For example, the properties of heat treated 410 chromium stainless show a maximum heat treated strength of about 190,000 psi with 10% elongation, 20% reduction in area, and 20 to 30 ft lb Charpy impact. Some of the low alloy high strength steels such as 6150, 8640, and 9440 have properties nearly identical to the titanium alloy. The titanium enjoys a considerable strength-weight advantage over these materials, however.

Col. B. S. Mesick, Commanding Officer of Watertown Arsenal and Army Titanium Coordinator, announced the alloy development. Stanley Abkowitz, Materials Engineer at the Arsenal Laboratories and Supervisor of the Armour Contract said tests conducted at the Laboratory indicate that the new alloy overcomes the brittleness present in commercial high strength titanium alloys currently in production.

**Radioactive sprue bushing is inserted in a modified transfer mold to test erosion rate.** *General Electric Co.*

# Isotopes Lead to Improvement of Materials

Better knowledge of how metals flow in extrusion presses and development of low erosion plastic molding materials are two of the latest advances in production technology which are attributable to radioactive trace materials.

Based on the ease with which minute amounts of radioactive materials can be detected, the two new projects are representative of the growing use of materials made artificially radioactive for research applications.

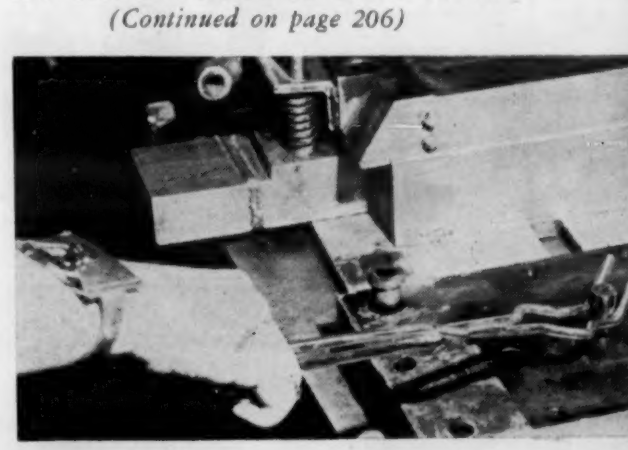
The Aluminum Company of America is using radioactive aluminum tracers to study metal flow during extrusion. In order to determine the flow pattern, small wires of aluminum alloy are exposed to neutron bombardment in the atomic pile at the AEC's Oak Ridge. The radioactive wires are then inserted in holes drilled into an extrusion billet. Since the radioactive aluminum does not differ in any respect from the billet material, the ingot is in all respects homogenous, and after it is extruded, the flow of metal tagged by the thread of radioactive material reveals how the base material behaves under extrusion conditions. The radioactivity of the extruded metal may be gaged by a geiger counter or a sectioned sample placed on photographic film, which gives a detailed picture of the flow of the radioactive sample.

Alcoa engineers report that they are getting accurate data for the first time on flow patterns, temperature, force distribution and similar basic information on metallurgical changes during extrusion.

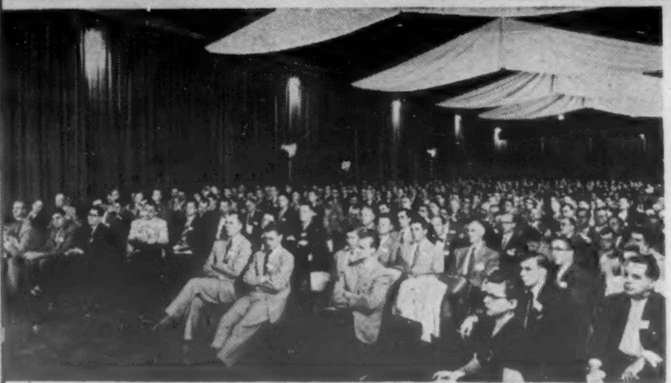
In a different field, the Chemical Materials Department of the General Electric Company reports the development of a new low erosion phenolic molding compound as a result of the use of radioactive tracers.

Erosion in large metal molds caused by plastic compounds is a major cause of die wear and has been a more or less unknown quantity in estimating die life. As a direct result of the experimental program, a low erosion version of G.E.'s 12882

*(Continued on page 206)*



**Small plug of radioactive aluminum alloy, inserted in an extrusion ingot of the same alloy, provides a method for determining behavior of metal during extrusion.** ***Aluminum Co. of America.***






# 2nd Basic Materials Conference and Exposition

At the Second Basic Materials Conference held in mid-May in Chicago, designers, engineers and executives from all over the country were asked to review, critically, the materials from which their products are manufactured. They were asked to make this critical review in the light of the constant stream of improvements in materials which flow from industrial research and technological development.

In his introductory remarks to the meeting, Chairman T. C. Du Mond pointed out "progress in materials might mean to the public the development of a glamorous new metal such as titanium or magnesium or some other material to which we can attribute magical or Cinderella-like properties. But to the engineer, the improvement of a material to the point where it can be used at temperatures only 200 degrees higher, to where it has hardness a few points higher, or where its tensile strength is raised a few thousand psi is much more important. The glamorous materials are few, the improvements are many."

Conference attendees were told of many improvements in materials and of advances in the knowledge of materials by experts in specific fields. The Conference provided a platform at one place and time for direct comparison of the qualities, properties and uses of materials ordinarily separated by the effect of specialization in research and engineering. Speakers rounded up developments in metals, plastics, ceramics, elastomers, and other non-metallics in the light of proper use, processing, joining methods, and resistance to corrosion and temperature. The meeting concluded with the presentation of a paper on Materials Management.

### *Weapons Research and Materials*

Out of the billions of dollars spent on the development of weapons and armaments come many new material applications and occasionally new materials useful to industry (the fluorothene resins are one shining example). Carson E. Hawk, of the Liquid Engine Division of the Aerojet General Corp. told the Conference how rocket development has posed extreme temperature and pressure problems, and how the solution of these problems stands to help industry as it heads for higher and higher pressures and temperatures in its search for power and efficiency. The speaker reviewed progress in high temperature coatings, high strength precipitation hardened steels, aluminum-stainless steel combinations, and temperature and corrosion resistant plastics. He pointed out "the weapon industries have substantially added to the over-all materials knowledge . . . through their rigorous requirements [which] encourage accelerated development in many fields."

### *New Forming Processes*

New methods of forming metals lead directly to new uses of both old and new materials: Three speakers discussed developments.

*(Continued on page 14)*


This 25-ton induction stirrer is fastened to the bottom of a 90-ton capacity electric arc furnace.
ELLIOTT
One of the coils for the stirrer, made of Revere rectangular copper tube. Coil is 12 feet long, over 6 feet wide.
When steel is produced in an electric arc furnace it is highly desirable to stir the molten metal, to assure uniform heat and avoid stratification of the various alloy constituents. Manual and mechanical methods have been used, but the most modern method is electrical—induction stirring. This is accomplished by sending low-frequency two-phase currents through copper coils immediately under the furnace. The magnetic field thus produced stirs the melt most effectively. Stirring can be reversed, and the contents of the furnace made to flow toward either the slag door or the pouring lip.
Because of the heavy currents required, copper's high electrical conductivity makes it essential. Since the stirring coils are close to the furnace, they must be water cooled, distilled water being used in a closed system. Copper's high thermal conductivity is vital here. The basic copper for the stirrers made by Elliott Company, Ridgway, Pa. for Aros Electric, Inc., New York, is Revere rectangular tube, .945" x .750", .157" wall. Elliott and Revere technical personnel worked closely on the problem of specifications, arriving at joint agreements on tolerances and temper suitable for bending. These proved successful from the start, again showing the value of close collaboration between Revere and its customers . . . If you have a problem in connection with copper and its alloys, and aluminum alloys, consult Revere. See the nearest Sales Office.
Revere Copper helps stir molten steel
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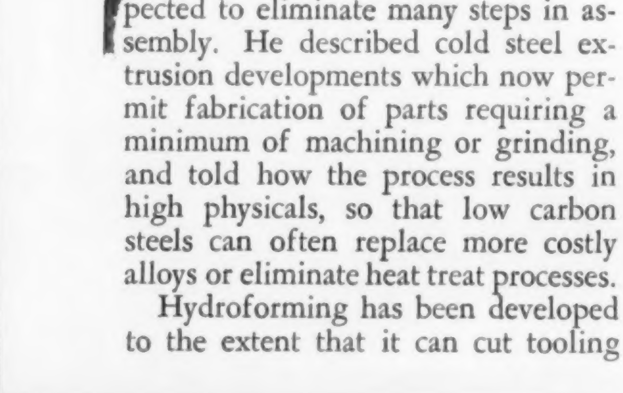
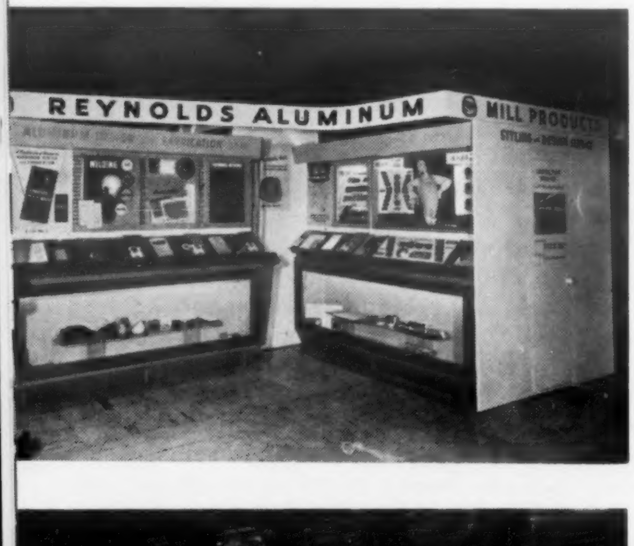
● *Forging, Stamping, Extrusion* J. W. Guliksen of Worcester Pressed Steel Co. summarized the current trends in metal forging, stamping, and extrusion. He told how the heavy forging press program is opening new possibilities for higher strength-weight ratios in large parts and is expected to eliminate many steps in assembly. He described cold steel extrusion developments which now permit fabrication of parts requiring a minimum of machining or grinding, and told how the process results in high physicals, so that low carbon steels can often replace more costly alloys or eliminate heat treat processes.

Hydroforming has been developed to the extent that it can cut tooling costs, replace several press operations with a single forming pass, and cut finishing costs significantly. Stamping and deep drawing have been adapted to new materials, and where it was once considered a cheap way of producing parts to approximate dimensions, it is now practical to mass produce precision parts to close tolerances at tremendous cost savings. Guliksen believes that many products should be re-appraised in the light of the gradual, steady progress in the techniques of stamping and drawing, particularly the less common materials, such as clad metals, stainless steels, and titanium.




● *Precision Casting* Sand should not be overlooked as a precision casting mold medium, according to L. M. Christensen, Castings Design Consultant to Northrup Aircraft. He showed the Conference audience several examples of unusual precision castings produced in sand molds—one, sixteen feet long, was an experimental wing, cast in two halves, clamshell style. Christensen also discussed the relationship of materials, properties and production quantity to sand, permanent mold, and investment precision casting techniques.

● *Powder Metallurgy* H. H. Hausner, of the Atomic Engineering Div., Sylvania Electric Products Inc., told the conference that powders other than pure metal had great futures as materials for powder metal parts. Materials such as SAP (sintered aluminum powder with 8% to 16% aluminum oxide content) show superior strength characteristics. It is less well known, perhaps, that in certain cases it is also advantageous to use hydride powders instead of metal powders for high density parts. Powder metallurgy is becoming more useful in production of larger parts with the perfection of rolling techniques to produce long sheets. Sinter welding is a promising method for joining powder metal parts through the use of a compound of the same metal in powder form. Slip casting and extrusion may also extend the uses of metal powders, Hausner believes.

### *Non-Metallic Materials*

More uses for more non-metallic materials appear almost daily. Among this large group of materials, plastics, of course, come first to mind, but glass, ceramics, carbon and graphite, and elastomeric materials are equally vital in the production of products.

● *Plastics* "Plastics should be used for their unique advantages and never, I repeat, *never* as substitutes" warned Dr. Jesse H. Day, editor of the *Society of Plastics Engineers*. Dr. Day compared developments in plastics to those in metals; he said, "We don't need radically new kinds of materials to make progress. Steel men have been making genuine improvements in the same old iron for years by making special alloys and by special methods of treatment. Look for progress in plastics in the same direction. Plastics analogous to alloys are the copolymers; and plasticizers and fillers provide special-purpose modifications. Other tricks are coming up—graft polymers may permit reacting a silicone with the surface of thermosetting plastic, giving an effect analogous to case hardening". Boiling down the answer to the question "Where, when, and how to use plastics" to an irreducable minimum, Dr. Day listed four

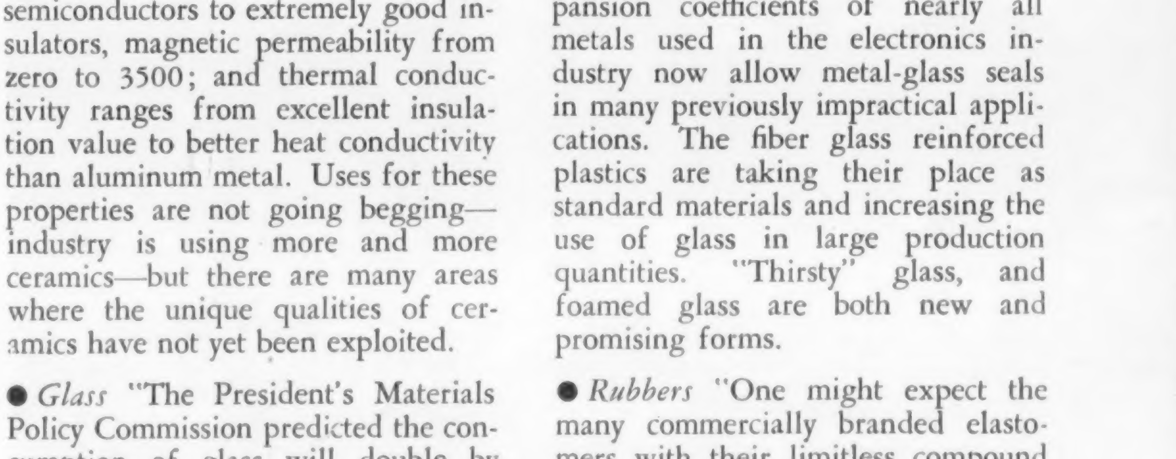
points: "1. Use plastic where it will do a job nothing else will. 2. Use plastic where it will do a better job. 3. Use plastic where it is capable of fulfilling its requirements and will add a positive factor, such as appearance, economy, lower noise level, textural feel, and so forth. 4. Use plastic as a material of choice for its strong engineering virtues, never as a mere substitute."

● *Carbon and Graphite* Carbon-graphite combines some exceptional physical properties with some basic disadvantages. Fremont Rule, of the United States Graphite Co., pointed out that it is worth designing around the material's limitations in order to take advantage of its unique characteristics as an engineering material. Listing high inherent hardness, thermal shock resistance, corrosion resistance, controllable porosity, dimensional stability, low density, and high melting point as advantages, Mr. Rule warned that proper use is possible only if the design and application takes into full account the disadvantages of brittleness, low tensile strength, low coefficient of expansion (not necessarily a disadvantage), and propensity to oxidize at high temperatures.

● *Ceramics* On the Exposition floor (cement), one of the favorite demonstrations of a ceramics exhibitor was to throw an irregular-shaped insulator on the floor as hard as possible, then catch it as it bounced up two or three feet and hand it to a prospective customer. It started a lot of people thinking about the engineering properties of ceramics. For those who missed that demonstration, the paper delivered by Prof. Edward Smoke (co-authored by Prof. Koenig, both of Rutgers School of Ceramics) had a similar impact. Prof. Smoke characterized ceramics as materials having a range of properties begging for tough problems to solve. Their melting points range from 1100 to 6500 F, compressive strengths from 50 to 332,000 psi, expansion coefficients from 14 to $-6(\mathrm{x}10^{-6})$, resistivities range from those of conductors through a whole range of semiconductors to extremely good insulators, magnetic permeability from zero to 3500; and thermal conductivity ranges from excellent insulation value to better heat conductivity than aluminum metal. Uses for these properties are not going begging—industry is using more and more ceramics—but there are many areas where the unique qualities of ceramics have not yet been exploited.

● *Glass* "The President's Materials Policy Commission predicted the consumption of glass will double by 1975. A large part of this expansion will naturally result from the expansion of the economy. Perhaps the most important part however, will be the glass industry itself, whose continued search for new properties and manufacturing techniques will materially affect the conditions of our industrial and domestic economy", concluded W. H. McKnight, Supervisor of Engineering Development of Corning Glass Works. He backed up this estimate of growth with evidence that the engineering use of glass will increase at an even greater rate. Glasses of improved heat resistance and resistance to thermal shock are widening uses in heat exchangers; photosensitive glasses can be etched to produce holes or contours of extremely fine grain; and glass matching the expansion coefficients of nearly all metals used in the electronics industry now allow metal-glass seals in many previously impractical applications. The fiber glass reinforced plastics are taking their place as standard materials and increasing the use of glass in large production quantities. "Thirsty" glass, and foamed glass are both new and promising forms.

● *Rubbers* "One might expect the many commercially branded elastomers with their limitless compound modifications, to meet all structural needs. Actually, the engineer designer too often faces critical needs for a rubbery structural material which does not exist. Close inspection reveals that elastomers are disappointingly few in basic type and amazingly alike in general properties: tensiles below 6000, dropping sharply with increasing temperature, a narrow temperature range of rub-






beriness, and generally poor oxygen stability." W. H. Faull, Jr., consultant to the ONR on Elastomer Research and Development warned the Conference that the limitations of rubbery materials must be well understood before specifying elastomeric materials in designs. He pointed out that from a practical point of view, rubberiness is a property which can be introduced at will, to almost any degree, in a large number of engineering materials such as the plastics. While this imparts shock resistance to brittle materials, a corresponding decrease in tensile strength must be recognized.

### *Adhesive Bonding*

The present state of adhesive bonding of plastics and metals was characterized by George Epstein of North American Aviation as "the educational phase for industrial adhesives". He said, "Engineers and other technical personnel are now learning the why and how of adhesive bonding. Once they have gained confidence in the method, increasing numbers of applications will be found and engineers will design specifically for adhesive bonding in order to utilize fully its vast potential". Among the advantages inherent in adhesive bonding he listed: ability to join dissimilar materials without danger of galvanic corrosion, elimination of high temperatures or structural damage during joining, capacity to join extremely thin sheets, sealing action which produces leak proof joints, insulates and damps vibration, provision of uniform stress distribution, good fatigue properties, reduced weight, and smooth surface contours.

### *Materials Management*

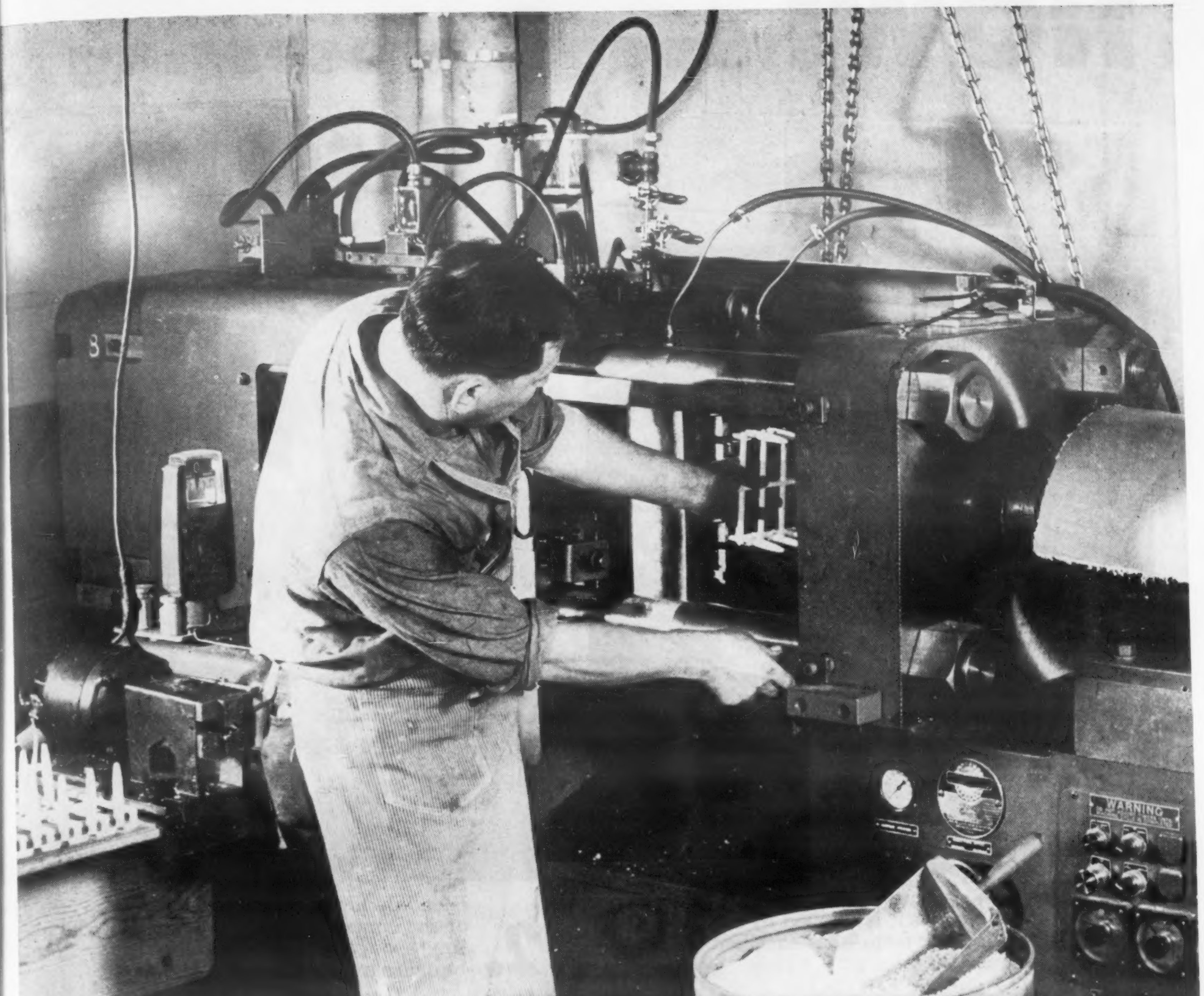
Merritt A. Williamson of the Burroughs Corp. Research Center held the anchor position in the list of Conference speakers. His excellent talk on *How to Set Up and Operate a Materials Department*—which also contains many hints for good management and public relations in general—will be reprinted in full in the August issue of MATERIALS & METHODS.

### *Materials Exposition*

Side by side in booth after booth filling Chicago's International Amphitheater, producers of engineering materials exhibited their products for the examination of engineers, designers and executives looking for ways to improve their manufactured products. Because displays were strictly limited to materials suppliers, the Exposition was unique in offering an opportunity for direct comparison of the widest possible range of the basic raw materials of industry. Glass, plastics, metals and alloys, cermets, coatings, wood, rubbers, felts, and many others were represented in demonstrations of where and how they could be used most effectively.

Technical representatives of the exhibitors who staffed the booths reported a general atmosphere of high technical competence stemming from visitors alert for suggestions on bettering the products they manufactured.

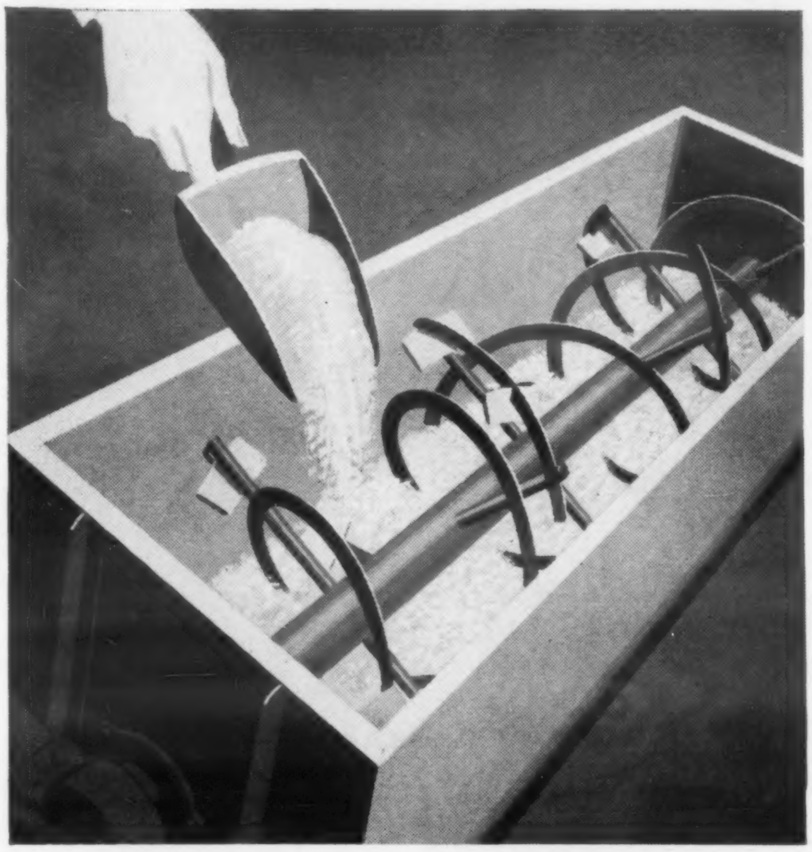
"It's a different kind of show with a different atmosphere", said one exhibitor, "It seems to start people thinking about their products from the ground up—not just, 'How can I make a design improvement or add a new machine to the assembly line?' These people seem to be thinking in terms of really basic changes which will result in new and better products or truly significant cost savings."



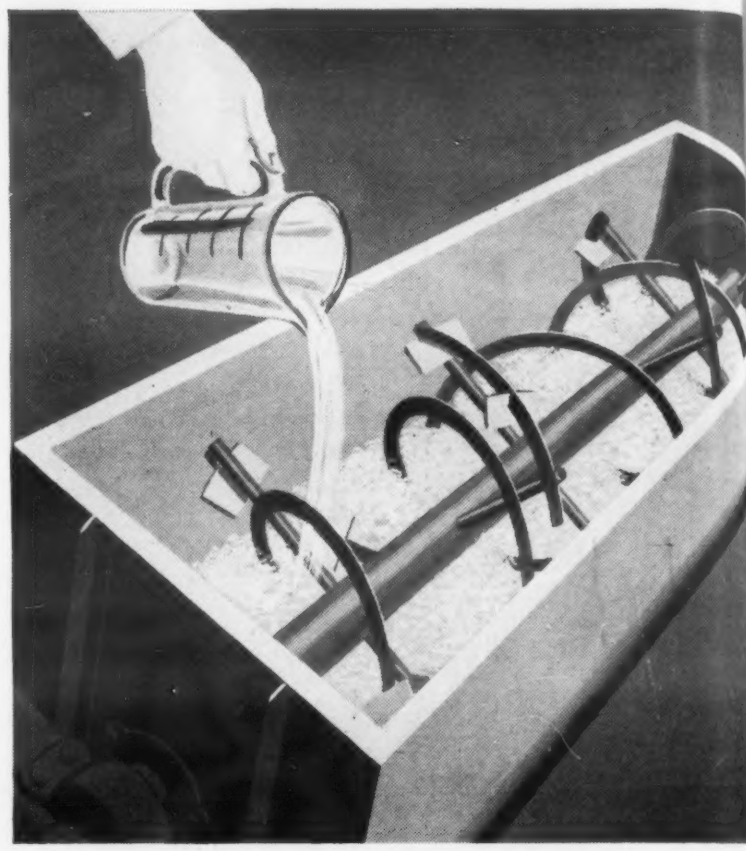

**NOW YOU CAN ADD** injection molding to many other methods of forming and fabricating the versatile PLIO-TUF resins. Easy molding PLIO-TUF is now available in pigmented granules. Photo courtesy The West Company.

# NOW! Speed processing..

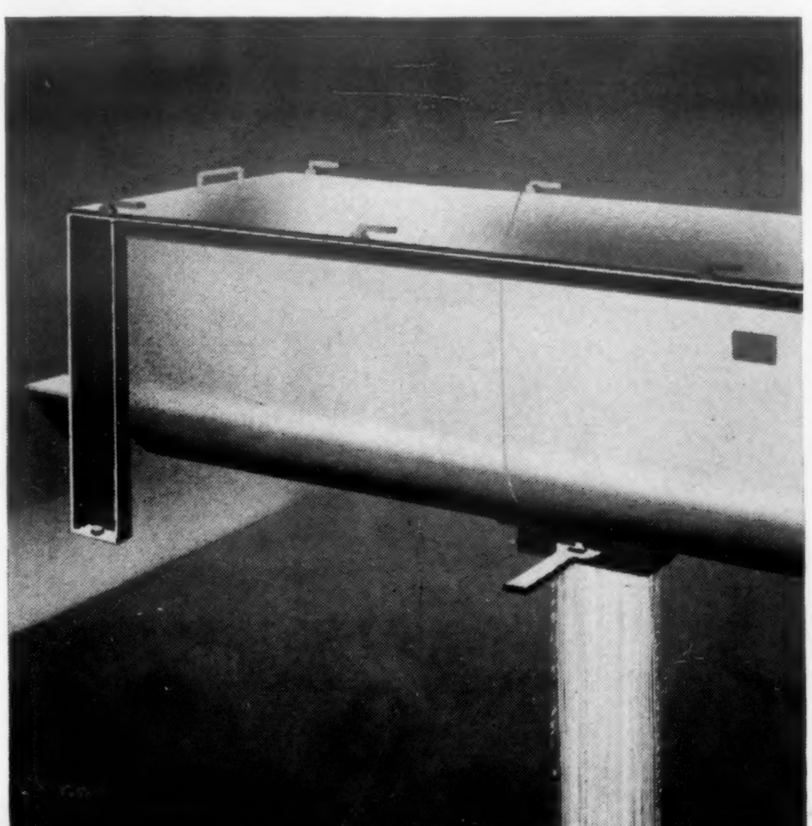
# with Firestone's



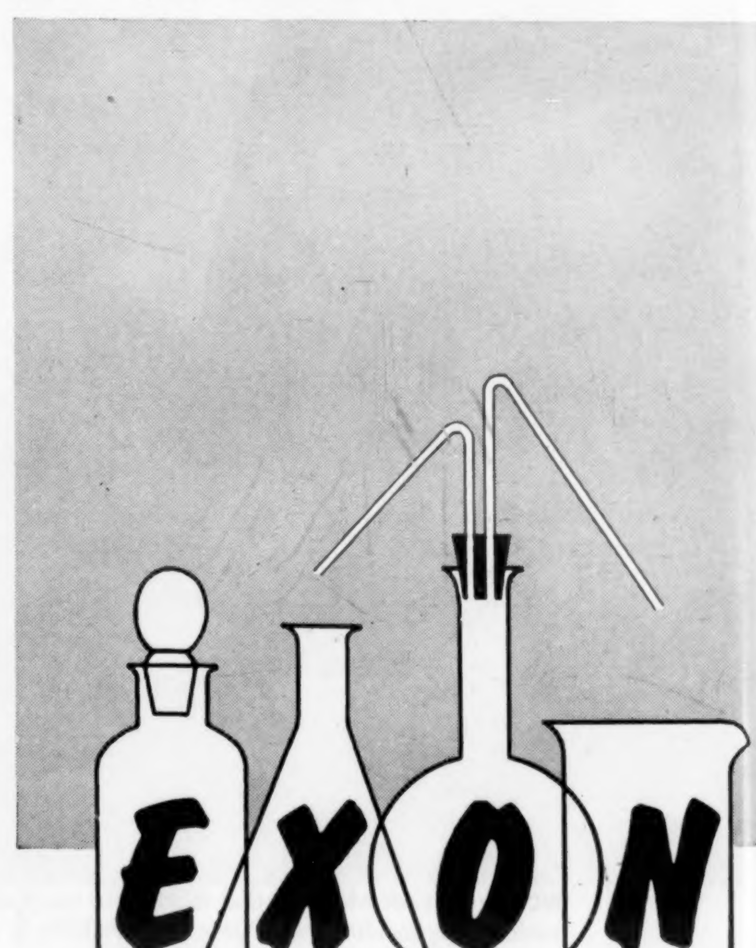
1. In preparing a sample formulation, picture shows Exon 500 resin as it is shipped by Firestone. It is in white powder form—has excellent dry blending characteristics.



2. Blending liquid plasticizer with Exon 500. Eac of the controlled particles of Exon 500 act as tiny sponge, quickly and completely absorbin liquid ingredients.



3. Result! A complete Exon 500 resin compound ready for the hopper. The formulation is free-flowing, lump free. Milling and pelletizing is never necessary.



Materials & Methods | July, 1954

# —One Point of View

### *The Materials Show—in Retrospect*

It is now almost two months since the Second Basic Materials Show and Conference was concluded. In many respects it was a successful affair. It certainly was from the viewpoint of the individuals attending the technical sessions and visiting the exhibits. Our proof of this lies in the interesting letters we have received from various people who attended. The chief drawback as we and our correspondents see it is the lack of support on the part of the materials producing industry.

Some of our larger materials producers feel they have been stung on some shows held in the past. Thus, apparently, they are sour on any new ideas. If not that, then they assume the attitude: "Let's sit back a couple of years and see what happens". In other words, let George do it. When he makes a success of it we'll climb on the band wagon.

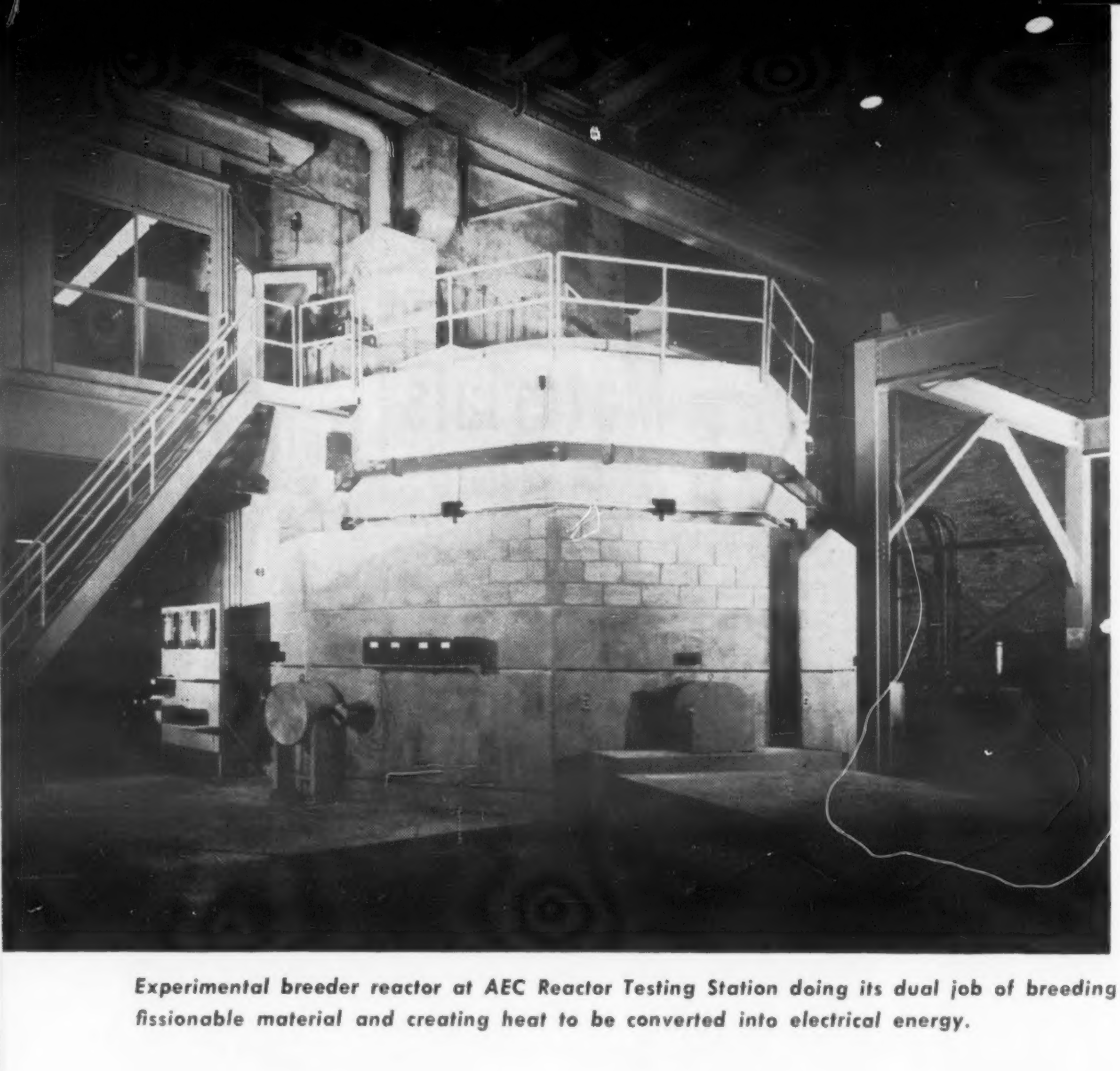
Theoretically editors are not supposed to concern themselves with sordid commercialism. However, there are times when one must be practical.

For years we have preached to our readers that they should do everything possible to use the right material in the right place. We feel it is the duty of every engineer to himself, his company and his customers to select and use engineering materials with the utmost intelligence. Now the Materials Show and Conference serve as a focal point where engineers can look for answers to their materials problems. Thus far, only the more intelligent and adventuresome materials producers have taken advantage of this opportunity to present their wares.

Here, in part, is what one visitor said in a letter to me: "My feeling is that it was very much of a success too. I found materials there which I did not know existed and their application promises to simplify some of our problems." The whole idea of the Show and Conference is well summarized in another portion of this same man's letter when he said: "I was impressed by the interest of the delegates in this kind of a conference. It was evidenced in the number and content of questions passed in for discussion. To me, this indicated the fact that the premise upon which the conference was based was correct, namely, that engineers need a clearing house for an interchange of ideas with those producing basic materials for their use."

We think Clapp & Poliak, Inc. deserve considerable credit for having conceived and established the Materials Show and Conference. We will continue to support it to the utmost of our ability and above all, we want to urge all who see this page to give their support to the Third Basic Materials Show and Conference to be held in Philadelphia next June. The dates are June 12-16, 1955.

T.C. Du Mond



*Experimental breeder reactor at AEC Reactor Testing Station doing its dual job of breeding fissionable material and creating heat to be converted into electrical energy.*

# Materials Problems in Nuclear Power Reactors

***In designing reactors, many of the problems commonly encountered in high temperature service equipment must be met. But there are additional ones, such as the effect of irradiation on the construction materials, to further complicate materials selection.***

by **HENRY H. HAUSNER, Atomic Energy Div., Sylvania Electric Products Inc.**

● MOST OF THE current nuclear reactor problems concern materials. Probably the major role in the development of economically practical power reactors depends on their proper selection. There are still many unsolved problems in reactor engineering and considerable research and development work is required in this field.

The following data indicate operating conditions of some power reactors presently in the design stage. They concern mainly the types and temperatures of the fuel and coolants under consideration.

The gas-cooled reactor proposed by Commonwealth Edison in Chicago is designed for solid uranium fuel elements with an internal temperature somewhere between 1000 and 1300 F. Helium is proposed as the coolant gas with an inlet temperature near 450 F and an outlet temperature in the range of 700 to 750 F, assuming a gas flow of approximately 3.27 x $10^6$ lb per hr. The total heat released will be in the order of $10^6$ Btu/hr.

The reactor proposed by the Dow-Detroit Edison Co. is designed for a liquid metal coolant such as sodium. The coolant temperature could be somewhere between 800 and 1100 F. A similar, but not identical, reactor has been proposed by the Monsanto Chemical group.

The thermal reactor designed by the Pacific Gas and Electric Co. uses water as a coolant (water temperature at inlet 380 F, at outlet 500 F, water pressure 1000 psig). The water temperatures are indicative of the temperatures which are to be expected in these power reactors.

All the reactor elements, the fuel, coolant, coolant transportation system, the moderator, any internal structural materials, and the reactor control elements will necessarily operate at elevated temperatures. The materials problems in the design of reactors are, therefore, characterized by the behavior of metals and the reaction between metals at elevated temperatures and under irradiation. These problems include: (a) mechanical behavior at elevated temperatures, especially strengths, such as tensile strengths, creep, impact and fatigue strengths, and stress-to-rup- of clad metal parts at elevated temperatures, (c) corrosion behavior, (d) heat transfer and thermal conduction, (e) thermal shock behavior of metal-nonmetal combinations, (f) radiation damage.

Some of these problems are of a physical, chemical or metallurgical nature. There is no precise border line between physical, chemical, and metallurgical problems and one may say, in general, that they concern solid state phenomena. There are, of course, other materials problems connected with neutron absorption cross-sections of the reactor materials and the formation of radioactive isotopes in the removable components, while a problem of prime importance concerns the recovery of the unused fuel after removal from the reactor. It may be stated that many of these problems cannot be solved by classical methods, and consequently new methods must be developed. Only partial solutions to some of the problems have been achieved and security restrictions do not permit a complete discussion.

## Metallurgical-Mechanical Problems

These concern practically all the metals in the reactor, those for structural purposes as well as those which we may call operating parts, including the fuel metal, the fuel cladding, the coolant, the moderator, and the shielding.

The basic difference between the fuel metal and other common metal parts at elevated temperatures can best be described by the difference in the direction of heat flow. Common metals during heating usually *receive* the heat from the outside, whereas the fuel metals *produce* the heat internally from fission. While common metals can be heated from the outside to a uniform temperature throughout, the fuel metal producing heat under irradiation will always have a higher temperature gradient between the center of the fuel element and the surface. This gradient is a function of many variables, the most important ones being: (a) neutron flux, (b) shape and physical dimensions of the element, (c) type and circulating speed of the coolant, and (d) thermal conductivity of the fuel material.

Any mechanical calculations concerning fuel elements must take both this temperature gradient and the resulting stresses into consideration. These stresses, however, make predictions of the behavior of the elements very difficult. They affect the strength and creep properties as well as the stress-to-rupture values and the fatigue of the material.

In addition, these stresses are of prime importance in all problems concerning the bond between a solid fuel metal and the protective fuel element cladding. Any high temperature reactor utilizing solid metallic fuel elements needs a reliable bond between fuel metals and cladding, especially for heat conduction reasons. The cladding metal must be chosen very carefully. It requires a low neutron absorption cross section for neutron economy, its thermal expansion must approach that of the fuel metal and it has to resist corrosion under operating conditions. As the fuel elements operate at elevated temperatures, care is required to avoid diffusion of the fuel metal into and through the cladding during operation.

Difficult metallurgical-mechanical problems are encountered with the coolant and coolant transportation system when the coolant is a liquid. Liquid metals are highly desirable from the heat conductivity standpoint, and as long as the temperature conditions are stable, the mechanical problems concerning the liquid metal coolant are relatively simple. However, in cases of non-uniform temperature conditions, there is a danger that the liquid metal coolant may change its viscosity and with this, the friction conditions between coolant and the coolant transportation system. Non-uniform temperature conditions may therefore effect the circulation speed of the coolant and thus the heat transport itself. The mechanical problems in connection with coolant circulation pumps and the purification system will become immense if coolant viscosity changes.

Attention is to be given also to the reactions of the liquid metal coolant with structural reactor materials. Several types of attacks in liquid metals are possible, especially the direct solution of a material or its constituent, intergranular penetration, formation of intermetallic compounds, and others.

Another mechanical problem with respect to the coolant transportation system is leak tightness. The tightness of the coolant pipe lines, circulation pumps, heat exchanger, etc., is of greater importance in nuclear power stations than in ordinary power stations. In the nuclear power station, the radioactive coolant by penetrating any leaks in the system would cause damages and dangers (fire, radioactivity) hardly to be evaluated in advance and practically impossible to correct after the damage was done. If this happened, a complete enclosure for the reactor would be necessary. Of course, structural materials used in the reactor must be carefully chosen to withstand the temperatures and radiation encountered while at the same time avoiding undue neutron losses.

## Corrosion

Most of the corrosion problems in a nuclear power reactor are connected with the type, temperature, and pressure of the liquid coolant. There is a general agreement among reactor designers that the fuel material should be placed in a sealed container in order to prevent corrosion and erosion by the coolant. However, even in cases where the nature of the coolant does not promote corrosion, such as in the use of gaseous coolants such as argon, it will be necessary to clad the fuel material in order to prevent radioactive fission fragments from entering the coolant.

Some of the metals to be considered for cladding materials or for coolant pipe lines have been developed only recently and little is known about their corrosion behavior. Where liquid metals are used as coolants, there is a certain danger that they may react with the cladding material. Corrosion in a nuclear power reactor may take place at the following points: (a) between fuel cladding and coolant, (b) between fuel metal and coolant in case of an imperfectness of the cladding, (c) between coolant and coolant transportation systems, including the welded joints, and (d) between coolant and heat exchanger or heat engine.

Static corrosion tests are not sufficient for testing the materials under consideration, since the coolant in the reactor circulates under pressure at a fairly high speed. The reactor proposed by the Dow-Detroit Edison Co. is designed to use sodium at 800 to 1100 F as a coolant, circulating at a speed of approximately 30 ft per sec. One of the reactors planned by Commonwealth Edison Co. is designed for heavy water at approximately 420 F, circulating at 20 ft per sec. Corrosion problems are extremely difficult where welded joints must be used since rates of corrosion may be increased by the presence of alloys formed during welding.

Many investigations on the corrosion resistance of various metals and alloys in liquid sodium were made under static and dynamic conditions. Pure iron, ferritic stainless steel (12-27% Cr), and austenitic stainless steel (18-8 and 25-20 Cr-Ni) have shown excellent corrosion resistance up to high temperatures, whereas low chromium steels and mild carbon steels show only poor corrosion resistance at temperatures above 100 F. Zirconium does not corrode up to 1100 F in liquid sodium, but shows only limited resistance at 1470 F.

Temperature differentials in the flowing liquid metals result in interesting phenomena. Since solubility of a material in liquid metal depends on temperature, increased attack is possible by the so-called mass transfer process. Some metals dissolve in the hottest part of the coolant system

until the coolant is saturated at that temperature. This metal then precipitates in the cooler zones until saturation at the low temperature is reached. Mass transfer is a metallurgical problem which requires further careful investigation.

Recent research and development work is directed towards the application of ceramic materials for power reactor purposes. Among the ceramic materials for fuel elements with high melting points are Uranium oxide (5072 F), Uranium carbide (4892 F), and Uranium silicide (3092 F). Ceramic materials with high neutron-absorbing power include hafnium oxide and boron carbide. Corrosion tests have shown that ceramic materials offer many advantages in nuclear power reactors. However, their low resistance to temperature shocks makes the application of these materials still difficult.

## Heat Transfer and Thermal Conduction

The useful thermal output of a nuclear power reactor depends on the operating temperature and on the efficiency of heat transfer from the fuel element, where heat is generated, to the heat engine, where heat is transformed into mechanical and electrical power. In order to obtain good heat transfer, the problem of thermal conduction must be carefully evaluated in the design of reactors. Thermal conduction between fuel metal and cladding and between fuel cladding and coolant as well as between coolant and heat engine or heat exchanger has to be studied especially carefully.

Any variation in thermal conduction between fuel metal and cladding material can be detrimental to the reactor operation. The bond between fuel core and cladding must be satisfactory and reliable from a number of standpoints. Any non-uniformity in the bond can cause overheating in certain spots and in this way may cause stress, grain growth, and dimensional distortion. Hot spots also promote diffusion of the fuel metal into and even through the cladding material. In the latter case the coolant and eventually the whole system will be poisoned. The bond between fuel core and cladding therefore must not only be uniform but also must prevent diffusion of the fuel metal through the cladding material. The bond must further be temperature shockproof to protect against failure in case the reactor is suddenly shut down. The production of a satisfactory bond between fuel metal and cladding, although appearing to be a simple problem, actually represents a major one.

Another thermal conduction problem arises at the interface between the fuel cladding and the coolant. Poor wetting properties of the coolant or poor thermal conduction of coolant can hinder heat removal. As the materials for construction in a reactor frequently must be made from "uncommon" materials, this heat conductivity study represents entirely new problems in many cases. The cooling of the moderator system represents another difficult problem of heat conduction.

## Radiation Damage

Radiation damage is an important problem in reactor design and is a problem entirely different in nature from any other. Experience in this field is new and experimental results are still incomplete. Metallurgist and solid state physicists are still searching for a correct theoretical explanation for the phenomena observed.

During the last few years, it has been shown that the physical properties of many materials change under radiations. These changes vary with the type, density and duration of radiation, and also with the type and structure of the material. It is fairly well agreed at present that organic compounds are affected by beta, gamma and neutron radiation and the disturbances in the material can be well explained by ionization. Metals, however, being good electrical conductors, seem to be affected chiefly by neutrons. Some of the experimentally observed disturbances in metals can be explained and correlated on the basis of a lattice vacancy picture, which considers displacements of atoms from their normal crystal lattice positions. It is understandable that the kinetic energy of a fast neutron is high enough to displace atoms during an elastic collision and thus to disrupt the material. By such collisions, we may expect the creation of a number of lattice vacancies and the removed atoms may also displace still other atoms from the lattice. It is also possible that these displaced atoms excite lattice vibrations of a mean energy corresponding to a temperature higher than the average temperature of the material.

One of the most important results of radiation is dimensional change. This is often called "radiation damage" in the literature. It is interesting to note that most of the changes in the physical properties of metals on exposure to neutron radiation have a certain resemblance to the changes occurring as a result of cold working, although the mechanism of these two types of changes are of an entirely different nature. It also appears that a correlation exists between the degree of cold working, the heat treatment of a metal and the extent of changes under neutron radiation. *(Editor's Note: Detailed information and data on these changes will be given in a Materials & Methods Manual to be published in Aug. 1954).*

These effects are not yet understood completely and it is the opinion of the author and others that studies toward a correct explanation of radiation damage effects should be vigorously pressed and will be of great importance not only for reactor design but probably also for a better understanding of many other solid state phenomena.

The disturbances in metals caused by radiation represent one of the greatest materials problems in the design of power reactors, and the development work in this field may eventually lead to entirely new types of materials.

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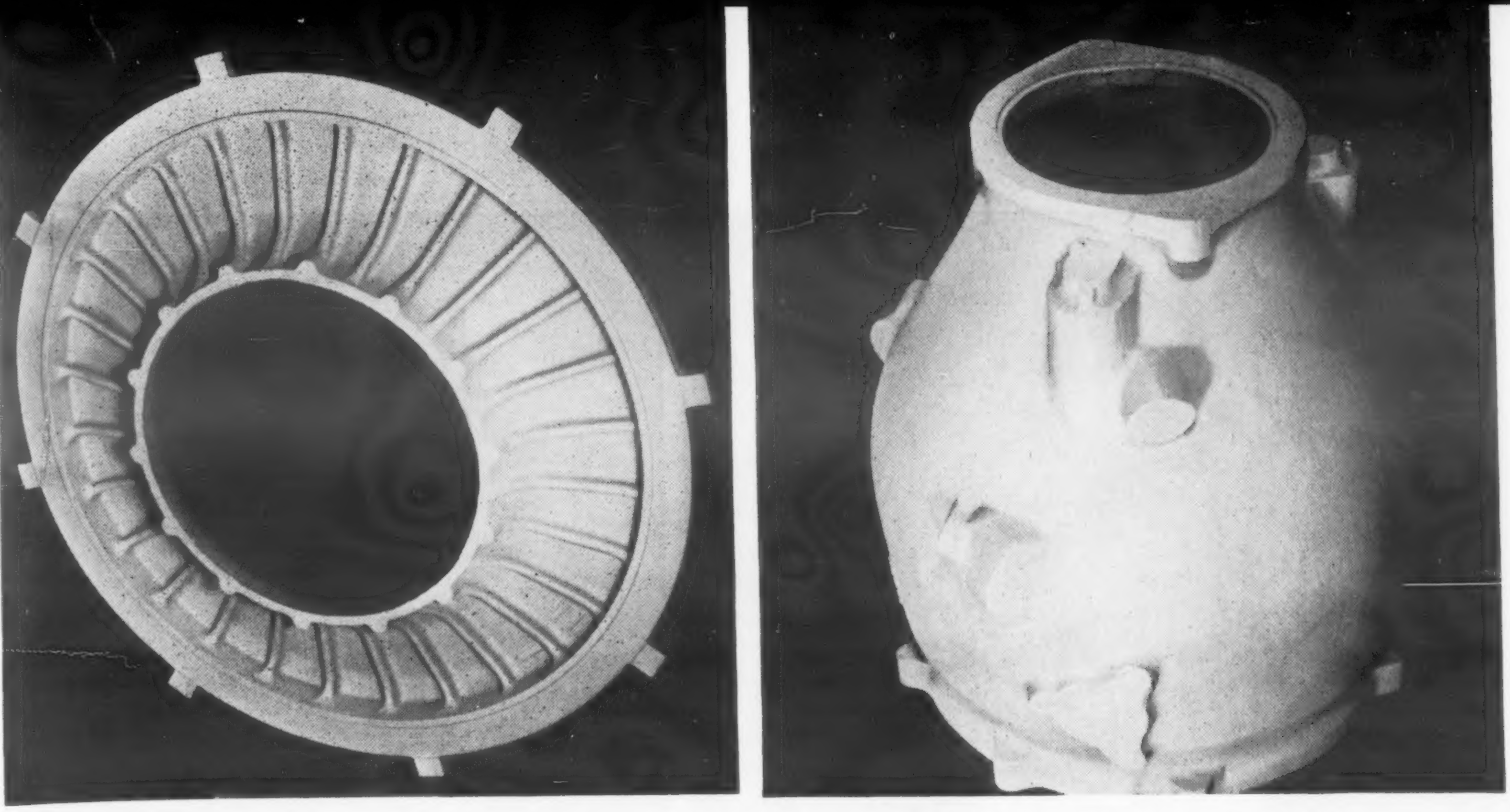


*These jet engine castings, made of magnesium rare-earth alloys, perform satisfactorily at temperatures up to 500 F.*

# Magnesium Casting Alloys for Elevated Temperatures

***Two families of alloys are now available:***

***1. Rare earth zirconium grades suitable for 350-500 F service***

***2. Thorium-zinc-zirconium grades for 500-700 F service***

**by KENNETH ROSE, Mid-Western Editor, Materials & Methods**

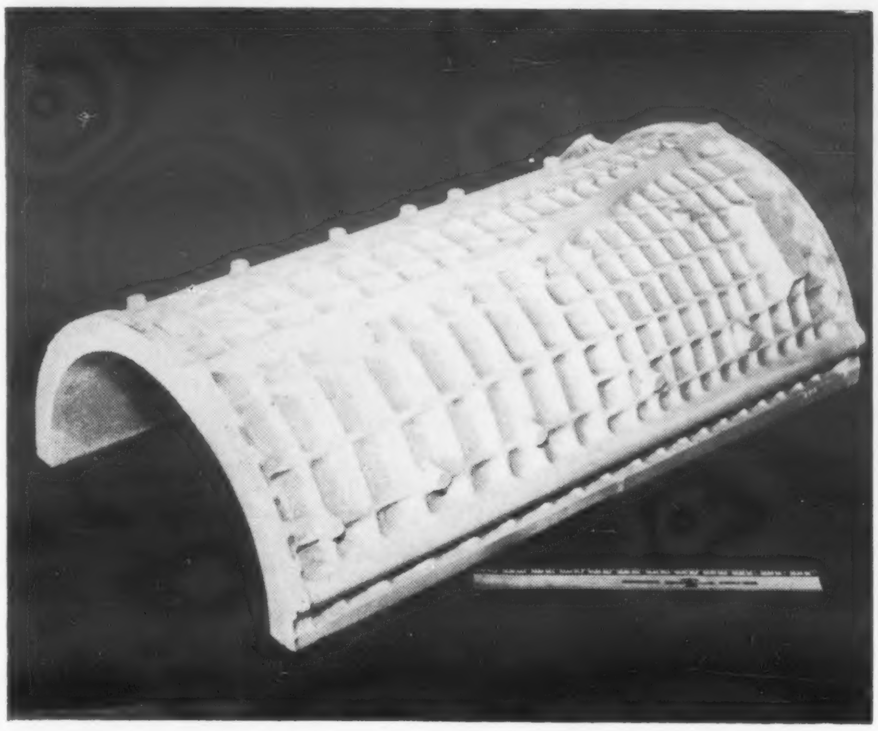
● ONE OF THE MOST important fields of application for magnesium has been in internal combustion engines, especially for aircraft. Other fields are opening or are possibilities for the relatively new magnesium alloys which retain a good proportion of their strength at temperatures several hundred degress above average air temperature.

There are two families of elevated temperature alloys of magnesium. One of these is based upon use of the rare earths as the principal alloying constituent, with zirconium added for grain refinement. The second family uses thorium as the principal alloying element. Here also zirconium is added for grain refinement, and zinc may be added for better mechanical properties at the higher temperatures, particularly for the long time creep strength. The use of zinc was a British development, but it is now in American compositions also.

Heat treatment improves creep strength of these alloys, but the solution heat treatment, requiring high temperatures while increasing short time tensile properties, greatly increases the danger of distortion in the piece. This distortion, however, is not to any degree greater than that obtained in solution heat treating the commercial magnesium-aluminum-zinc alloys. Heat treat temperatures for the important alloys of magnesium intended for elevated temperature service are given in Table 2.

**Table 1—Percent Composition of High Temperature Magnesium Alloys**

| Alloy | Rare Earths | Zirconium | Zinc | Thorium |
|---|---|---|---|---|
| EK30A | 3.0 | 0.2 min | 0.3 max | — |
| EK41A | 4.0 | 0.5 min | 0.3 max | — |
| EZ33A | 3.0 | 0.5 min | 3.0 | — |
| HK31XA | — | 0.7 | — | 3.0 |
| HZ32XA | — | 0.7 | 2.0 | 3.0 |



One of the main fields of use for elevated temperature magnesium alloys is in aircraft engines.

In jet engine parts, magnesium alloys have advantages of light weight and good creep strength.

## Properties

The alloys based upon the rare earths as the principal alloying elements are especially suitable for service in the 350 to 500 F range. The alloys having thorium as the principal added metal retain their strength and particularly creep strength, at higher temperatures—of the order of 550 to 700 F.

The four rare earth alloys commercially available, EK30A-T6, EK-41A-T5 and T6, and EZ33A-T5 have the nominal compositions shown in Table 1. They are covered by ASTM specifications. The rare earths are added as mischmetal. This is a mixture of closely related metals of the rare earth group containing about 50% cerium with lanthanium, neodymium, and praseodymium in varying amounts. The constituents other than cerium were at one time considered as little more than impurities, but research has shown that the mixed metals produce better results than pure cerium. All three alloys have closely comparable physical properties.

Typical strength properties for EK30A alloy in the solution treated and aged condition are given in Table 3. The effect of increasing temperature is shown by the results in Table 4, obtained with laboratory test bars.

The EK41A alloy can be heat treated by a solution treatment followed by a precipitation hardening, or by a precipitation treatment (at only a slight sacrifice in tensile properties) if it is desirable in order to reduce the danger of warpage. Typical properties for the alloy in both conditions are given in Table 3. Typical strength properties obtained in EZ33A in the artificially aged condition, and without the solution treatment, are given in the same table.

The effect of testing at elevated temperatures upon the strength properties of the EZ33A alloy is shown in Table 4. As can be seen from these figures, all of the rare earth-containing alloys begin to lose strength rather rapidly above about 400 F. Strength and castability are much the same for all of the four listed. Properties at 400 F and above are far superior to those of the standard magnesium alloys containing aluminum and zinc as principal alloying elements. Whereas creep strength of the rare earth-containing group would be about 8000 psi, at the 400 F temperature, the standard magnesium-aluminum-zinc sand casting alloys would show only about 1500 psi remaining at that heat.

For service temperatures up to 650 to 700 F, there are two magnesium alloys having thorium and zirconium as the principal alloying metals. These are designated HZ32XA and HK31XA, and have the nominal compositions shown in Table 1. Addition of zinc makes possible the use of the thorium-containing alloy without a solution heat treatment and gives better high-temperature long-time creep strengths. The HK31XA composition is given the complete heat treatment, consisting of solution treatment at high temperature and a precipitation or artificial aging treatment, and the HZ32XA receives the aging treatment only.

Room temperature strength properties of the alloys as determined from test bars in the laboratory are given in Table 3. Table 5 lists the

**Table 2—Heat Treatments for High Temperature Magnesium Alloys**

| Alloy | Solution Treatment | Aging Treatment |
|---|---|---|
| EK30A-T6 | 1050 F for 18 hr | 400 F for 16 hr |
| EK41A-T6 | 1050 F for 18 hr | 400 F for 16 hr |
| EK41A-T5 | — | 400 F for 16 hr |
| EZ33A-T5 | — | 420 F for 5 hr |
| HK31XA-T6 | 1050 F for 2 hr | 400 F for 16 hr |
| HZ32XA-T5 | — | 600 F for 16 hr |

strength properties for short time exposure at elevated temperatures.

## Which Alloy To Use

Comparing all the elevated temperature alloys and the standard sand casting alloys as to suitability for elevated temperature service, the standard sand casting alloys, such as AZ92A (Dowmetal C) and AZ63A (Dowmetal H) or the newer alloy ZK51A are suitable for use to about 200 F, and, if stresses are not too high, may give satisfactory service to about 350 F. AZ91C has been suggested as a replacement for AZ63A, which shows a tendency to produce porous castings. These alloys are lowest in cost and have good casting qualities.

The rare earth alloys are quite similar among themselves in their casting properties. They are more expensive, as the mischmetal added for alloying costs about $4.50 per lb. EK30A is usually the lowest in cost because of its lower zirconium content. All the rare earth alloys are usually quite free from porosity as cast, but are more liable to draws and misruns than the conventional aluminum-zinc series. They are, however, superior in strength properties at temperatures in the 350 to 500 F range, and they may make possible a lighter casting if strength rather than castability determines the thickness of section in the design.

When service requirements call for better properties than would be available from the rare earth alloys at temperatures above 400 F, the thorium-containing alloys should be considered. They are considerably more expensive than the rare earth alloys, and are more difficult to cast satisfactorily. Of the two, the HK-31XA alloy is superior to HZ32XA in tensile and yield strengths up to about 700 F and is superior in creep in short time total extension values for lower testing temperatures. HZ-32XA is better in long time creep strength at the higher testing temperatures.

A proper selection of a material for a given application cannot be made upon the basis of service temperature limit alone. Stresses and durations for both maximum and normal temperatures should be considered in the selection. Knowing the limits of stress and the length of time of operation at any given temperature, a proper selection can be made.

**Table 3—Room Temperature Properties of High Temperature Magnesium Alloys**

| Alloy | Treatment | Tensile Strength, psi | Yield Strength, psi | Elong in 2 in., % | Compressive Strength, psi |
|---|---|---|---|---|---|
| EK30A | Sol. Treat. and Aged | 23,000 | 16,000 | 3 | 16,000 |
| EK41A | Prec. Treat. | 23,000 | 16,000 | 2 (min) | 16,000 |
| EK41A | Sol. Treat. and Aged | 25,000 | 18,000 | 3 (min) | 18,000 |
| EZ33A | Aged | 23,000 | 16,000 | 2 (min) | 16,000 |
| HK31XA | Sol. Treat. and Aged | 37,000 | 18,000 | 8 | — |
| HZ32XA | Aged | 32,000 | 15,000 | 10 | — |

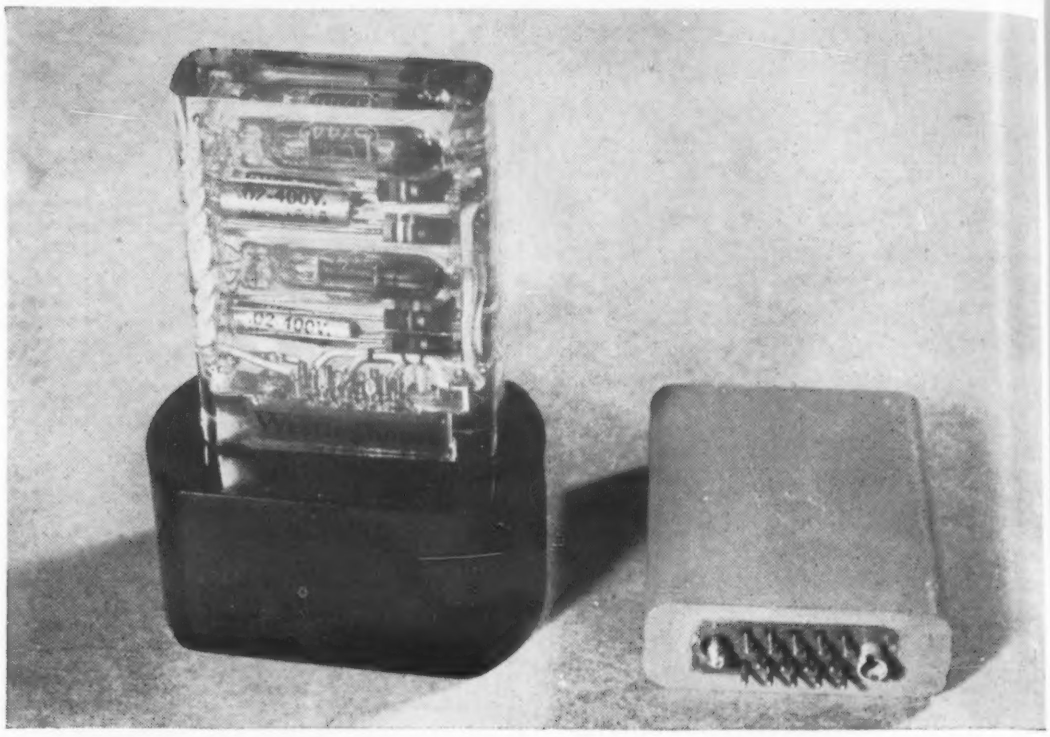
**Table 4—High Temperature Properties of EK30A and EZ33A Alloys**

| Alloy | Tensile Strength, psi | Yield Strength, psi | Elong in 2 in., % | Stress for 0.2% Elong in 100 hr |
|---|---|---|---|---|
| EK30A | | | | |
| 70 F | 23,000 | 16,000 | 3 | — |
| 400 F | 20,000 | 14,000 | 18 | 7200 |
| 600 F | 12,000 | 7000 | 56 | 1500 |
| EZ33A | | | | |
| 70 F | 22,000 | 16,000 | 3 | — |
| 400 F | 21,000 | 10,000 | 21 | 7500 |
| 600 F | 12,000 | 8000 | 50 | 1400 |

**Table 5—Short Time High Temperature Properties of HK31XA and HZ32XA Alloys**

| | Tensile Strength, psi | Yield Strength, psi | Elong in 2 in., % |
|---|---|---|---|
| HK31XA | | | |
| 400 F | 26,000 | 14,000 | 17 |
| 500 F | 24,000 | 14,000 | 19 |
| 600 F | 20,000 | 12,000 | 22 |
| 700 F | 14,000 | 9000 | 26 |
| HZ32XA | | | |
| 400 F | 18,000 | 10,000 | 33 |
| 500 F | 14,000 | 9000 | 39 |
| 600 F | 12,000 | 8000 | 38 |
| 700 F | 11,000 | 7000 | 29 |

by W. A. ERNST,
Materials Engineering,
Westinghouse Electric Corp.




Clear resin is used as embedding medium on new circuits to show areas of maximum stress as reflected by physical failures. When proper spatial arrangement of parts has been determined, units may be cast in opaque material (right).

- *Reduce Weight*
- *Simplify Design*
- *Cut Repair Time*

# Plastic Embedded Miniature Unit Circuits

● AIRBORNE ELECTRIC GEAR must, in general, be provided with insulation and protection against severe climatic conditions and physical damage which might occur either in shipment or in service. These requirements are frequently met by the application of molding and casting techniques employing various types of synthetic thermosetting resins. The increased use of these casting resins followed the trend to miniaturized and lightened circuitry, necessitated by aircraft spatial and weight restrictions.

The application of casting resins for the embeddment of miniature components has led to a new design concept in electronic circuitry, namely unitization. While molding of conventional size circuitry is rather impractical due to the weight and volume of the molding medium required, the haphazard molding of miniaturized circuits is equally impractical since it is impossible for the design engineer to eliminate all types of electrical failure.

This led to the development of logical component grouping. Now, replaceable, unitized, functional components, and complete standardized assemblies such as feedback, networks, oscillators, modulators, and a.c. amplifiers can be embedded as a complete unit. The molded units are plugged into a chassis which also contains miniature tubes and some permanently mounted components of a highly reliable nature, such as transformers and magnetic amplifiers. All components are mounted on the side of the chassis, which is accessible upon quick removal of the equipment cover and only wiring remains under the chassis.

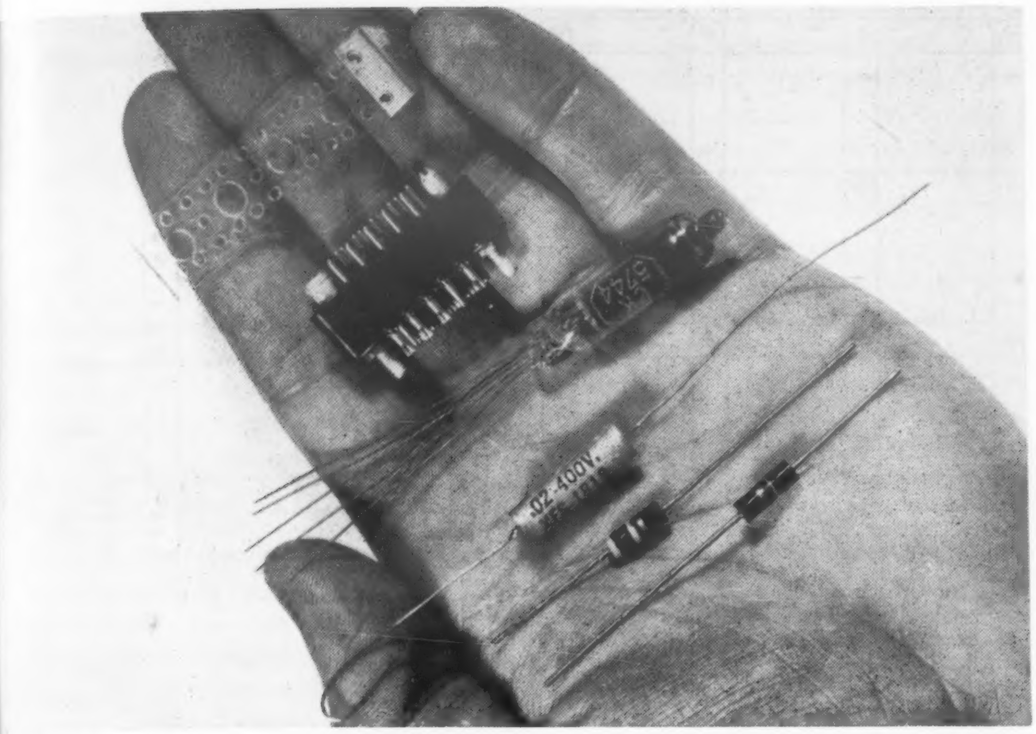
This development reduces the maintenance problem in the field, since all components may be examined at one glance for any obvious defects. Further, by using known good spare units, trouble-shooting by successive replacement of good units for units in the equipment can be done by relatively untrained personnel. In the event that trained personnel is available, trouble-shooting and repair time can be reduced considerably over that needed for conventional equipment, since by using readily available chassis test points, trouble can be isolated to a small block of molded units and the defective molded unit quickly found by using a molded unit tester which is very similar in operation to a tube tester.

Once the engineer has grouped the networks functionally, the individual components are examined and located carefully to minimize local heat build-up and conditions producing excessive strain, i.e., sharp corners and gross differences in cross sectional area of the embedding resin.

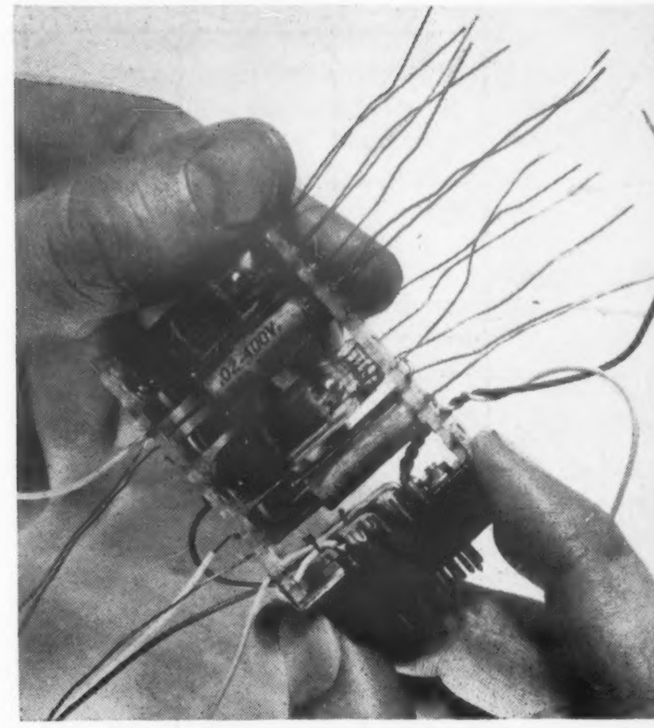
## Plastics Used

Most plastics have a relatively high coefficient of thermal expansion and poor thermal conductivity. In addition, polyester type casting resins are accompanied by a high shrinkage rate during polymerization. All of these factors combine to provide points of high local stresses that can result in failure either during cure or under conditions of thermal shock. While these faults cannot be eliminated from the casting resins, the use of a filler such as pulverized silica or alumina very markedly improves the embedding compound. Powdered silica, for example, used in a ratio of 1:1 with a polyester resin, will approximately double the thermal conductivity and halve the coefficient of thermal expansion and the shrinkage during cure.

Miniature tubes generally radiate more heat per square inch of surface than conventional tubes. This makes rather severe demands on the thermal stability and severely taxes the strength of the adjacent resin at elevated temperatures. This problem has been eliminated by first encasing heat



*Individual miniature components for aviation electronic circuit are comparatively delicate and require careful assembly.*



*Components assembled on pinched plastic end supports and fastened to plug-in socket.*

generating elements in silicone rubber, which provides a heat resistant, resilient, cushioning envelope between the embedding resin and the critical tubes. The effect of severe differential thermal expansion is thus reduced when the equipment is turned on under conditions of a very low ambient temperature.

On newly designed circuits, it has been found helpful to use a clear resin for embedding the miniature assemblies in order to point up areas of maximum stress as reflected by physical failures. This might not be apparent in an opaque material. An accompanying illustration shows the mounting and construction detail of one type of miniaturized potted circuit produced by Westinghouse which has been cast in a clear polyester resin. The construction is quite simple and would be almost flimsy by conventional standards. Yet, the only structural requirement for the assembly is maintenance of the spatial arrangement of components until the embedding resin has been cured. A rigid, protected, integral structure is the result.

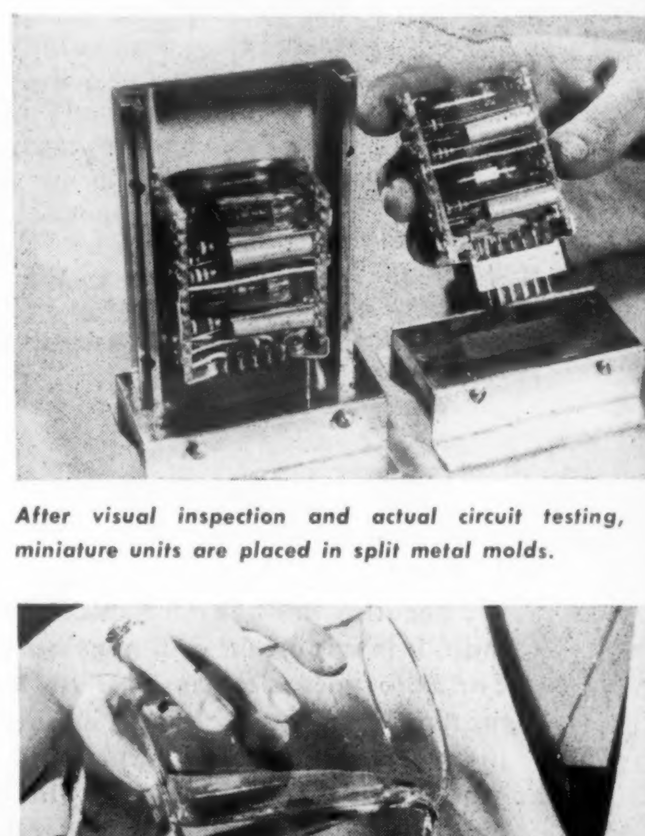
## How It's Done

The equipment required for embedding miniature circuits is quite simple. Metal or plastic molds may be used, and in the latter case, a single metal master pattern may be utilized in conjunction with a plastisol (polyvinyl chloride dispersion in plasticizer which fuses and becomes solid upon the application of heat) to produce all of the necessary molds for production purposes. A simple vacuum system is also necessary to remove entrapped air and bubbles from the liquid resin before curing.

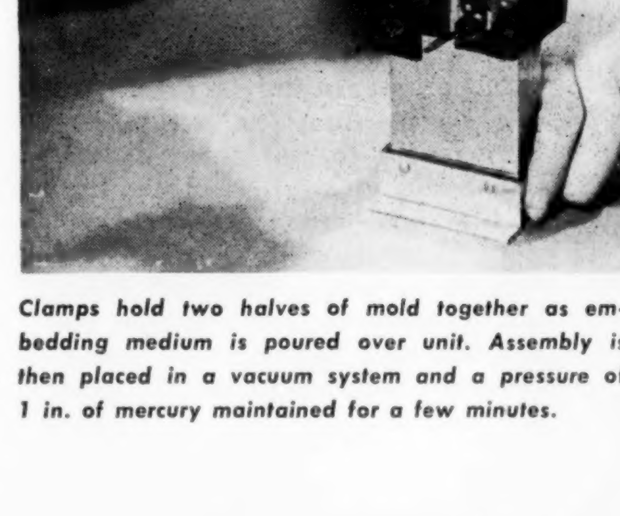
Briefly, the procedure used for embedding the assembled miniature networks is as follows:

Heating elements are encapsulated with a silicone rubber. The coated unit is then placed in the mold and the embedding medium, typically a polyester-silica filled compound to which has been added a catalyst, is poured into the mold. The assembly is then placed in a vacuum system and a pressure of about 1 in. of mercury maintained for a few minutes. The pressure is released and the units are allowed to cure at room temperature overnight. They are then stripped from the mold, the assembly finished as though it were a conventional plastic part, and tested electrically.

The successful adaptation of molded, unitized electronic circuits depends initially upon close contact between the chemical engineer and the design engineer to insure the proper selection and use of a molding resin that is adaptable to the desired volume of production. The cumulative experience now being gained with relatively high volume production of embedded, unitized structures is being transferred to more and more commercial and civilian consumer products with the advantage of increased reliability and lower maintenance costs.



*After visual inspection and actual circuit testing, miniature units are placed in split metal molds.*



*Clamps hold two halves of mold together as embedding medium is poured over unit. Assembly is then placed in a vacuum system and a pressure of 1 in. of mercury maintained for a few minutes.*

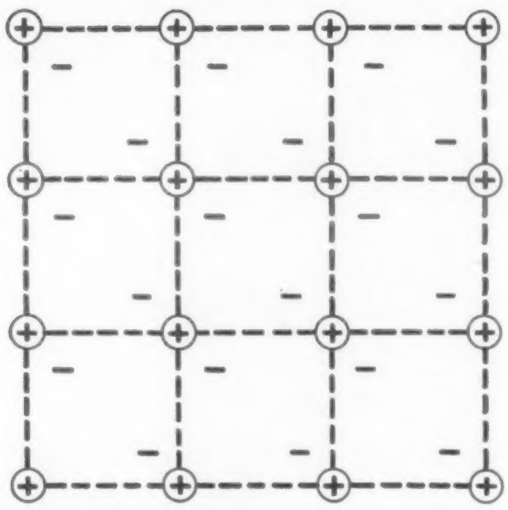


*Fig 1 Conductor*

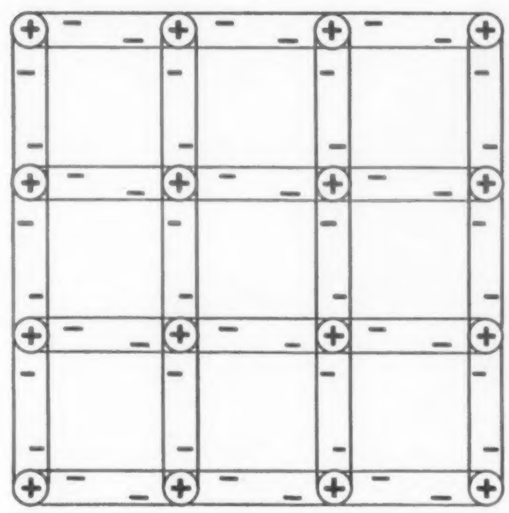


*Fig 2 Semiconductor*

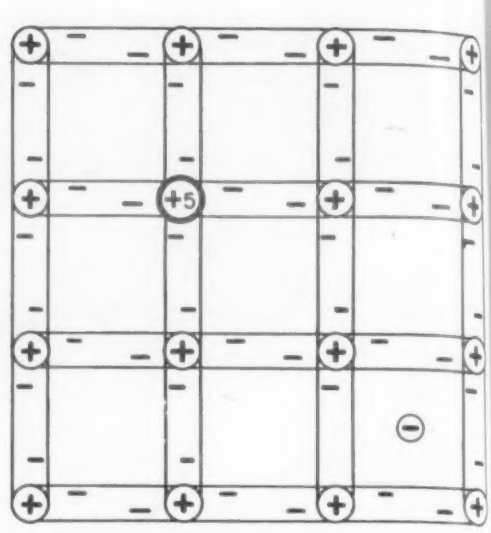



*Fig 3 Doped Semiconductor*

# Semiconductors

## WHAT THEY ARE HOW THEY WORK

by T. R. LAWSON, JR. Materials Engineering Dept., Westinghouse Electric Corp.

**Because the use of semiconductors is becoming increasingly common, it is important and necessary that a knowledge of the limitations and idiosyncracies as well as the vast potential of semiconducting materials be shared by the engineers and designers who will be using them. This first of two articles is designed to familiarize the lay engineer with semiconductors. In it, basic operational principles are outlined which lead to an understanding of the problems faced in the field. A second article to appear in a subsequent issue will round up the progress to date in the development of semiconductors and the materials used to protect them from temperature, corrosion and contamination.**

● SELDOM HAS ANY group of materials so quickly vaulted into a position of prominence, or so greatly aroused the imagination of the technical public as have the semiconductors, as exemplified by the transistor. On the other hand, the detailed mechanism of conductivity in semiconductors is not widely understood. This may be due in part to their peculiar electrical properties — they are quite literally half conductor, half insulator; but another contributing factor is the unfamiliar electrical concept—that of the flow of "holes" as well as electrons—commonly used to describe the passage of current through the material. Semiconductors have other unusual characteristics, but considered on a fundamental basis, and non-mathematically, their operation is less difficult to follow.

The conductivity of semiconductor materials, as the name implies, lies between those of conductors and insulators. The resistivity range of semiconductor materials does not have sharp boundaries, but lies approximately between $10^{-2}$ ohm-cm and $10^{6}$ ohm-cm (for comparison, copper resistivity is about $1.7 \times 10^{-6}$ ohm-cm and Neoprene is of the order $10^{12}$ ohm-cm). But perhaps the most definite criterion of a semiconductor is its anomalous change in resistivity with temperature. Instead of increasing with temperature, as do most conductors, the resistivity of semiconductors decreases, i.e., these materials have a negative temperature coefficient of resistivity. The temperature range for which this behavior holds depends on the particular semiconductor and may not be

room temperature. The thermistor is an application of this property.

Another identifying factor is a scarcity of "free" electrons, common in conductors. Herein lies another distinction between conductors, semiconductors, and insulators. In a conductor, the outer ring of electrons in the atomic structure becomes a mobile matrix cementing the atoms together. The electrons in the matrix are free to move and provide a means of conduction. In a semiconductor or insulator, the valence electrons take part in a relatively stable bond between atoms. As will be seen, they are an integral part of the bound-together collection of atoms that constitute the material. Considerable energy is necessary to shake these electrons free of their atoms. One difference between a semiconductor and an insulator lies in how easily these valence electrons can be freed for conduction purposes. The energy required to break a bond in an insulator is large compared to the energy required in a semiconductor.

These three factors—conductivity between that of insulators and conductors, negative temperature coefficient of resistivity, and type and degree of binding force—are means of identifying semiconductor materials. Obviously, semiconductors are unique material, with some charcteristics of conductors, others of insulators, and some unique to themselves.

A fourth, and sometimes troublesome characteristic of semiconducting materials is the extent to which their electrical properties depend on impurity content, method of preparation, and heat treatment. For example, while the resistivity of conductors is relatively insensitive to crystallographic imperfection and heat treatment, even minute variations in these factors have a drastic effect on a semiconductor's resistivity.

## How Conductors Conduct

Consider first the mode of conduction for a normal conductor, such as copper. The metals commonly used to carry electric current are formed from many almost identical crystals. These crystals are made up of atoms built together in a definite form. The mechanism of cohesion between these atoms (the "metallic bond") is not fully understood, but it is known that the electrons attached to the outermost orbit of each atom (valence electrons) become free, that is, they no longer belong to any individual atom. In any given metallic crystal, a certain number of free, or mobile, electrons for each nucleus are present in the crystal, approximately $10^{22}$ electrons per cubic centimeter. When an electric field is applied to this type of crystal, the mobile electrons are attracted or repelled, as the case may be, and move with considerable rapidity. The ease with which electron motion occurs is represented quantitatively by two figures called the "specific resistivity" and the "mobility of electrons" in the material in question. Mobility need not be considered here, but more must be said about resistivity. The larger this figure becomes, the more difficult it is to pass current through the metal. Typical resistivities of common materials at room temperature are shown below.

| | |
|---|---|
| Copper | $10^{-6}$ ohm cm |
| Iron | $10^{-5}$ |
| Aluminum | $10^{-5}$ |
| Germanium | (99.9999%) 0.1 |
| Silicon | (99.9999%) 1 |
| Bakelite | (140) $10^{7}$ |
| Celluloid | $10^{10}$ |
| Shellac | $10^{16}$ |

## How Semiconductors Conduct

In the so-called semiconductor materials, the mode of conduction and the order of resistivities obtained are entirely different. Whereas in the metallic conductor, built with the metallic bond, the valence electrons of each atom are freed for conductivity, in the case of semiconductors, the valence electrons of the atoms are in relatively fixed bonding positions. They become an integral part of the sttructure of the material. A diagrammatic sketch of this difference in crystalline structure is given in Fig 1 and 2. The ideal case as given in Fig 2 is not obtained in nature. There is never a perfect combination of all electrons; some electrons are always available for conduction. These, however, are present in very minute quantities as compared to a normally conducting material.

A semiconductor is not merely a poor conductor. For example, graphite and various resistor mixes (graphite and clay) are poor conductors but not semiconductors. Even such poor conductors have vastly more free electrons than semiconductors, and no not have a negative temperature coefficient.

In a conductor, the valence electrons of each atom are not used in crystal structure and are so loosely connected to their respective atoms that even with the thermal energy present at very low temperatures they can be considered free, that is, no longer associated with a given atom. The resistivity of a conductor is largely determined by the degree of perfection of the lattice through which it moves. Theoretically, in a perfectly pure, flawless single-crystal conductor at a temperature of absolute zero, the resistivity is zero. Departures from perfect periodicity in the lattice give rise to resistance to motion of conduction electrons. Thus the thermal agitation of the atoms about their position of equilibrium gives rise to the characteristic increase of resistivity with increasing temperature.

## Electrons and "Holes"

An additional method of conduction occurs in semiconductors: the flow of "holes." Nearly everoyne has seen the game wherein a number of blocks are placed in a frame with one more space than there are blocks. The object of these games is to rearrange the blocks in a specific order by simply sliding the blocks and not removing any of them. The system used in the solution of these puzzles, if observed from a new light, illustrates that when a block is moved the space, or hole, is also moved. That is, even though the space has no mass, per se, it appears to move as the blocks, which do have mass, are moved. Again referring to Fig 2, if an electron were missing from one of its usual positions in the crystal lattice, a "hole" would exist. Under the proper conditions, an electron from an adjacent bond may fall into this hole. The hole, of course, then appears in the space vacated by the electron. Since the material shown in Fig. 2 was originally electrically neutral, when an electron is removed from this lattice, the area from which the electron was removed shows a net positive charge.

Both holes and electrons exist at the same time in semiconducting materials. At sufficiently low temperatures, each electron in a semiconductor is bound to an atom. At a higher temperature a few of the electrons will be released from the parent atom by thermal agitation and will be free to wander through the lattice in much the same fashion as electrons are released from gas atoms by ionization at extremely high temperatures. When an electron is removed

from its normal place in a crystal structure by thermal agitation, it simultaneously leaves a hole in the crystal structure.

Electrons can be injected into a semiconductor by the simple expedient of attaching an electrode to the semiconductor and applying a negative voltage to this electrode. Somewhat more difficult to visualize, but by the same process, holes may be injected into a semiconductor by attaching an electrode and applying a positive potential. A positively charged electrode possesses great affinity for electrons and attracts electrons in the vicinity of the electrode from their normal positions in the crystal lattice. Subtraction of electrons amounts to the same thing as the addition of holes, as long as electrons, injected from the other electrode, do not replace those subtracted. Therefore, a positive electrode can be used to inject holes in a semiconductor. As will be seen, this ability to add or subtract holes from semiconductors explains much of their usefulness in practical devices, such as rectifiers.

While holes and electrons can and normally do co-exist in the same specimen of semiconductor, the number of each that will exist at any time is governed by a mass action law similar to that applying to chemical reactions. A state of dynamic equilibrium exists, with electron-hole pairs being continually created by thermal agitation and destroyed by recombination.

## The Role of Impurities

The considerations thus far have pertained to a pure semiconductor. Such a material does not exist. All practical semiconductors have greater or lesser quantities of several impurities. Impurity concentrations greater than about 0.001% cause the semiconductor to lose its characteristic properties and behave more like a metal. However, when the concentration of the impurity becomes very minute, the quantity of the impurity and identity of the impurity determine, to a startlingly high degree, the properties of the semiconductor. For example, by extrapolation it has been determined that the specific resistivity of pure germanium is approximately 60 ohm-cm. The presence of as much as $10^{-4}$% of an impurity may reduce the specific resistivity of the same germanium to less than 0.1 ohm-cm. Reference to Fig 3 shows why this is so; here is depicted the presence of an arsenic atom in a germanium matrix.

Notice that arsenic has five valence electrons. Four of these are used in building the arsenic atom into the crystal structure of the germanium. The remaining electron becomes free for conductive purposes. Since extremely few conduction electrons exist in pure germanium at room temperature, the addition of even minute quantities of arsenic to germanium causes marked increases in conductivity.

Other elements having five valence electrons (such as phosphorus, antimony and bismuth), when they are impurities in germanium, cause the same increase in conductivity. Elements having only three valence electrons, when present as impurities in germanium, produce a deficiency of electrons—in other words, holes. Examples of these elements are aluminum, indium, and gallium. Semiconductors whose principal current carriers are electrons are known as *n* (for negative) type conductors. Those in which the principal mode of conduction is by holes are known as *p* (for positive) type conductors. A very minute difference in the quantity of impurity may change the mode of conduction of a semiconductor from that of *n*-type to *p*-type or vice versa.

The usual process of preparing semiconductor materials for device work is to purify the material to the highest degree possible. This material is usually—although optimistically — called intrinsic material; more accurately, intrinsic means 100% pure. A measured quantity of impurity is then added, just sufficient to produce the desired resistivity and conductivity type. This process of adding impurities is called doping, and the resulting materials are called doped semiconductors.

Both types of carrier are present in a semiconductor even if it is predominantly *n*- or *p*-type. In an *n*-type semiconductor, the electrons are called the majority carrier and the holes are called the minority carrier. The reverse is true for a *p*-type semiconductor.

Although holes and electrons can coexist in a given semiconductor body, they eventually combine. The average time in which a given free electron can exist in a semiconductor before combining with a hole is termed the lifetime of an electron. In many semiconductor devices, it is important that the lifetime of the minority carrier be made as long as possible, since it is the change in minority carrier that alters the conductivity of the semiconductor. The surfaces of a semiconductor crystal contain defects that tend to foster the recombination of holes and electrons. Since it is desirable that holes and electrons exist separately for as long a time as possible, it becomes apparent that the number of crystal surfaces should be reduced as much as possible. This is done by constructing semiconductor devices from single crystal material. Producing large single crystals of uniform prescribed resistivity is anything but an easy job. Herein lies one of the major stumbling blocks in the wider use of semiconductor devices.

Faults in the semiconductor crystal also produce regions of high rate of recombination of holes and electrons. A high recombination rate produces a low lifetime of minority carrier. Thus a usable semiconductor not only must be a single crystal, but that crystal must be as structurally perfect as possible. Lifetime of the minority car-

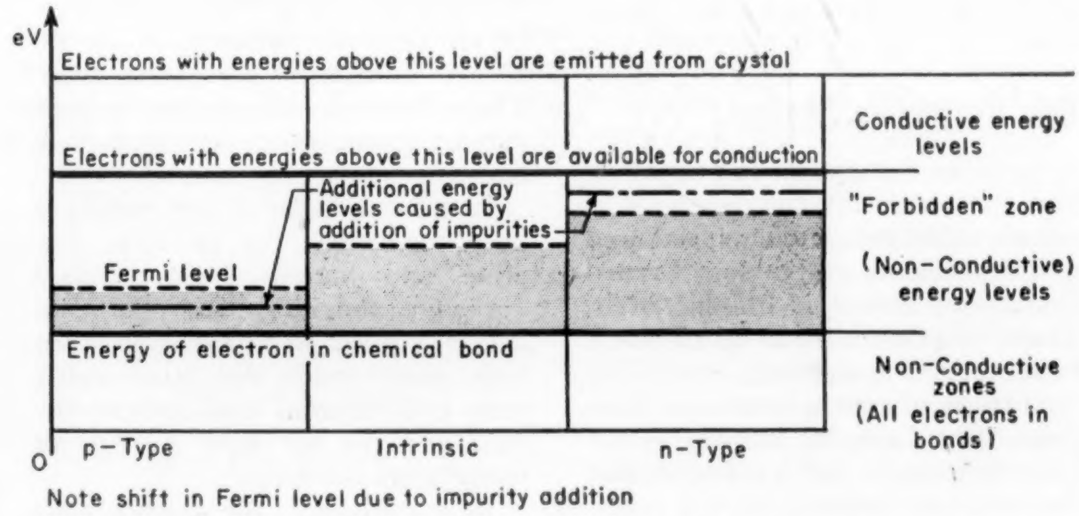



*Fig 4 Effect of impurity additions on energy levels of electrons in semi-conductors*

rier is a measure of the rate of recombination and, therefore, also a measure of the rate of generation of hole-electron pairs. It can be seen that if the minority carrier lifetime is low, generation of hole-electron pairs will be high.

## The P-N Junction

The simplest junction device is the p-n junction—a crystallographically continuous union of an *n* and *p* region of a semiconductor. This *p-n* junction has remarkable rectifying properties.

Let us re-examine the bond structure in a doped semiconductor. When donor atoms are present in the crystal, they provide electrons of much higher energies than those in the unexcited intrinsic semiconductor. Thermal agitation of the crystal at all ordinary temperatures is sufficient to ionize these electrons and thus provide free electrons for conduction (these electrons are in the excited state or conduction band). When acceptor atoms are present, they provide energy levels for electrons which are slightly above those in the unexcited state of the pure semiconductor. Consequently, thermal agitation of the crystal at all ordinary temperatures is sufficient to raise electrons from the unexcited state (or full band) to the slightly higher impurity levels.

Visualize what occurs when the conductivity type of a semiconductor changes abruptly within a single crystal. In two materials in close contact, whose average upper energy levels are different (see Fig 4), an electron flow occurs from the region of high electron energy to that of low electron energy. This transfer of charge will continue until the electrostatic energy of the dipole, built up within the semiconductor, just balances for former difference in average upper electron energies between the two types of semiconductors.

It is this dipole electrostatic potential barrier that produces the rectifying properties of an equilibrium *p-n* junction.

As can be seen from Fig 5, it is more difficult to move an electron by some external source from the *p*-type to the *n*-type region than the converse. Visualize what happens when electrodes are attached such that the *n*-type region is made positive with respect to the *p*-type region. The potential barrier is thus made much higher. The electrons present in the *p*-type region will have to climb this potential hill in odrer to carry current into the *n*-type region. This represents a high impedance to current attempting to flow in this direction. On the other hand, if the *n*-type region is made negative with respect to the *p*-type, the potential barrier is decreased and the current flow occurs much more easily.

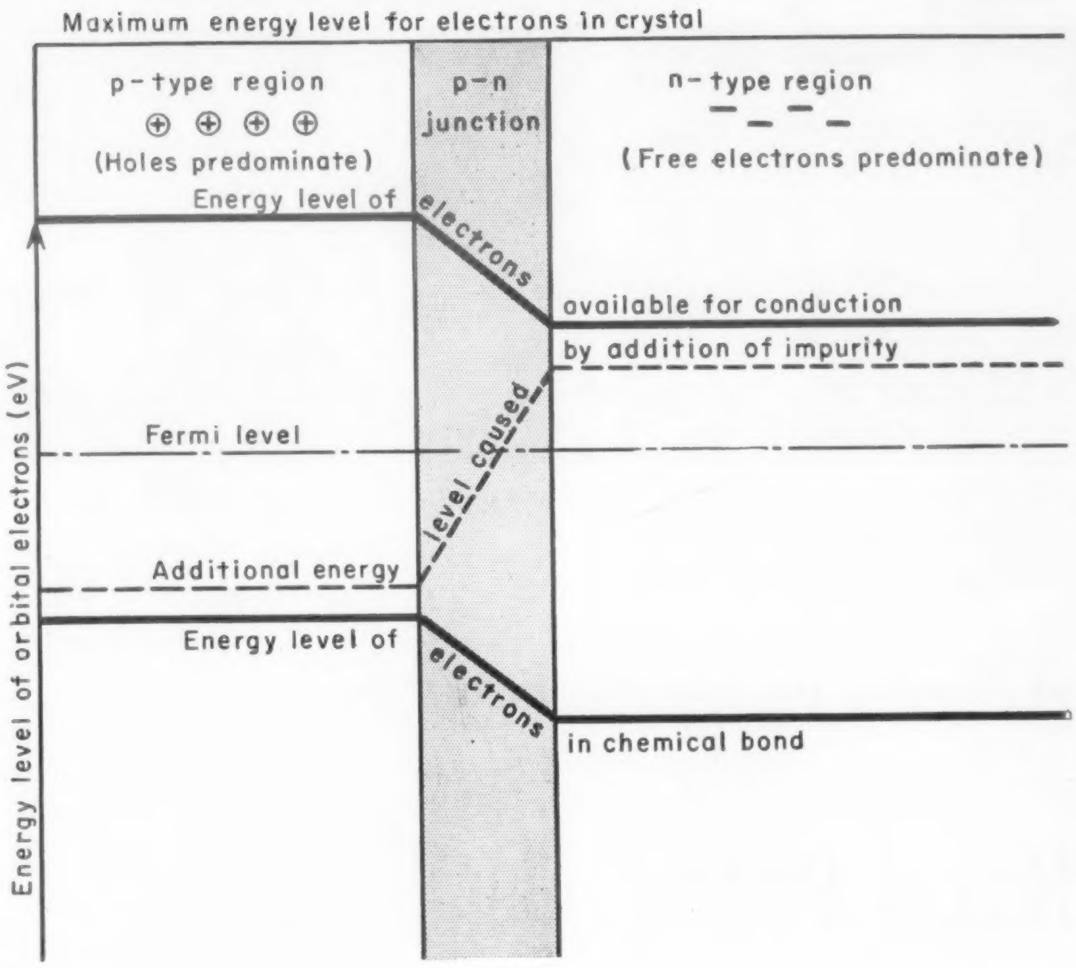


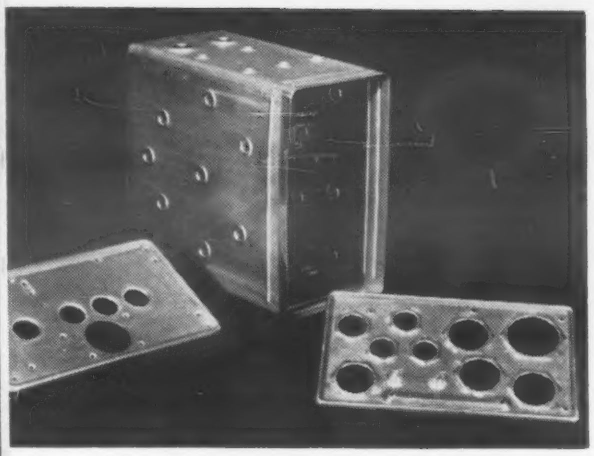

*Fig 5 p-n junction in semiconductor crystal*

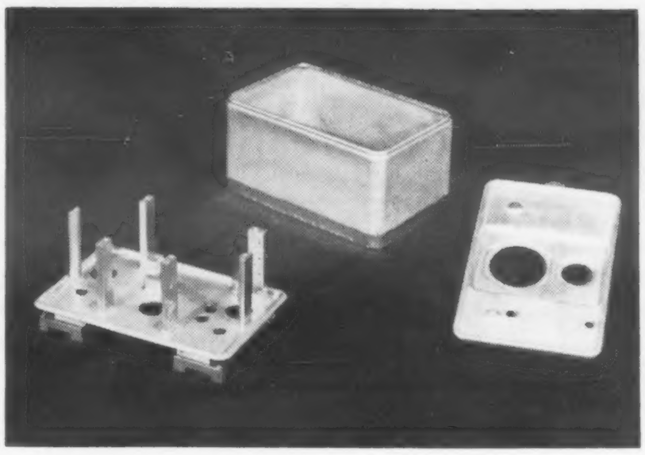
When lifetimes of injected carriers are large and the net rate of generation of carriers small, it is possible, by applying a field in the high resistance direction, to drain off the carriers from the edge zones of the *p-n* junction faster than they can be generated so that the concentration of carriers in these regions becomes very small. The current through the junction is then much smaller than that obtained in the equilibrium *p-n* junction, and furthermore, is independent of voltage, being determined by the diffusion currents from the bulk materials to these highly depleted zones.

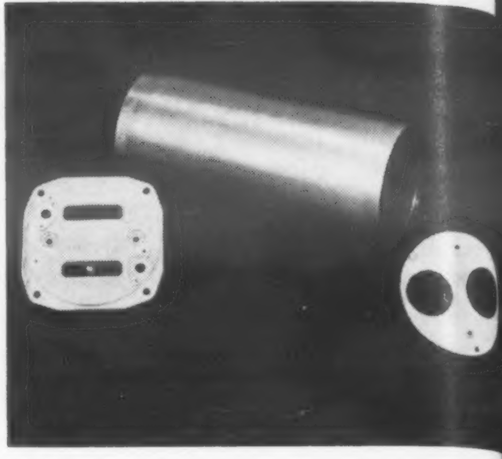
Semiconductor devices can do almost anything that vacuum tubes can do—amplify, rectify, oscillate, limit, count, etc.—more efficiently and in smaller space. Reliabilities are expected to greatly exceed those of vacuum tubes. They are presently limited in frequency response and noise level, but improvements are being made continually in the directions of better design configurations, purer materials, and new circuitry. The problem of limitation on ambient temperature of operation is being solved by the appearance of new devices perfectly stable to at least 300 F.

Technological difficulties continue to hinder the development and manufacture of semiconductor devices. For one thing, semiconductors are extremely difficult to purify to the extent required for semiconductor devices. Most chemical purification procedures are considered successful if the resulting material is 99.9% pure. In a semiconductor device, a purity of the order of 99.99999% is required. In addition, nearly all new devices require the use of single crystal material which is rather difficult to obtain. In many semiconducting devices exact control of geometries at the level of mils is required. Great strides, however, are being made in the solution of the problems.

The theory and application of semiconductors, while yet in its infancy, promises minor revolutions in the communications and power fields. On further development, such devices will change our concepts of electronic equipments.







*These aluminum cases, shown after nickel plating, can be resealed up to 10 times by soldering. Left to right: computer case, computer control case and indicator case.*

## *A joining problem is licked by....*

# Nickel Plating Aluminum

**by M. W. RILEY, Assistant Editor, Materials & Methods**

● ALTHOUGH NICKEL PLATING of aluminum is seldom done for corrosion protection, there are many specialized applications where it can be most effective in accomplishing a desired result. Solderability is a case in point. Soldering of aluminum presents many problems, and carrying out the operation on a production line basis is difficult. The nickel plate on aluminum parts has good solderability and an additional advantage is gained by the fact that the soldered joint can be broken and resoldered again and again.

The Ford Instrument Co., in the development of their navigational computer for the Air Force, used this property of nickel plated aluminum to solve a tough sealing problem. Three of the components of the navigational computer are the computer, the computer control and the indicator. The cases for these components are made of 61S-T6 aluminum sheet and 52SO aluminum forgings. After the assembly of the mechanisms inside the cases, the cases are soldered, hermetically sealing the mechanisms in an inert-gas atmosphere. One of the main requirements for the soldering of the cans is that they be resolderable, allowing the cans to be opened for repair or adjustment and then resealed.

Both cadmium and copper were considered as plating materials, but drawbacks encountered with both metals led to the selection of nickel. Soldering cadmium plate is a one-shot affair since the cadmium tends to go into solution with the normal 60-40 lead-tin solder used, and the joint cannot be opened and resoldered. Though the copper plate could be resoldered, the heat of the iron used in the open solder weld joint oxidizes the copper, and tends to break down the plate, reducing the number of resealing operations possible. With the nickel plate, the aluminum cases have been opened and resoldered up to 10 times without appreciable damage to the plate. A correlary benefit is derived from the corrosion resistance of the nickel plate.

## Why Is It A Problem?

There are two main difficulties in plating on aluminum. First of all each of the alloys of aluminum has a different metallurgical structure. The alloying elements may be present in solid solution in the aluminum lattice or as micro-particles of the elements themselves, or as particles of intermetallic compounds formed by the combination of the alloying elements and the aluminum itself. These various forms may have differing chemical and electrochemical reactivities, resulting in an inconsistent reaction to the plating material across the surface of the aluminum.

The other difficulty is the ever-present oxide film found on aluminum surfaces. In order to secure a bond of optimum strength between the aluminum and the plating metal, this oxide film must not remain between the two. The method of insuring removal of this film is by a replacement coating of another metal. Aluminum, being a less noble metal than most of the common ones, will readily replace many of them from solutions of their salts. This is the basis of the zinc immersion treatment. By immersing the aluminum in a sodium zincate solution, the oxide film is removed and replaced by a thin adherent film of zinc.

*The nickel plating line for aluminum parts includes the cleaning and zinc immersion tanks on the right and the plating and rinse tanks on the left.*

## How It Is Done

Since the ultimate success of the sealing operations depends on a high quality and adherence of the nickel plate, the technique developed by Ford Instrument is followed closely. First the parts are degreased thoroughly. They are then put through an alkali cleaning, rinsed, and immersed in sulfuric acid. After a subsequent rinse, they are soaked in nitric acid, rinsed again, and agitated in the sodium zincate solution.

To gain the best plating results, it was found that after the first zinc coating was applied, the zinc should be stripped in nitric acid and the whole cleaning operation repeated before the final zinc coating is applied.

After removal of the parts from the sodium zincate solution they are rinsed thoroughly and immersed in the plating tanks which are "alive" at the time of immersion, in order to assure immediate plating with no loss of the zinc coating. The plating solution is maintained at a temperature between 70 and 90 F with a current density of 5 to 15 amp per sq ft of work surface. Plating is continued until thickness of the nickel reaches 0.0005 in.

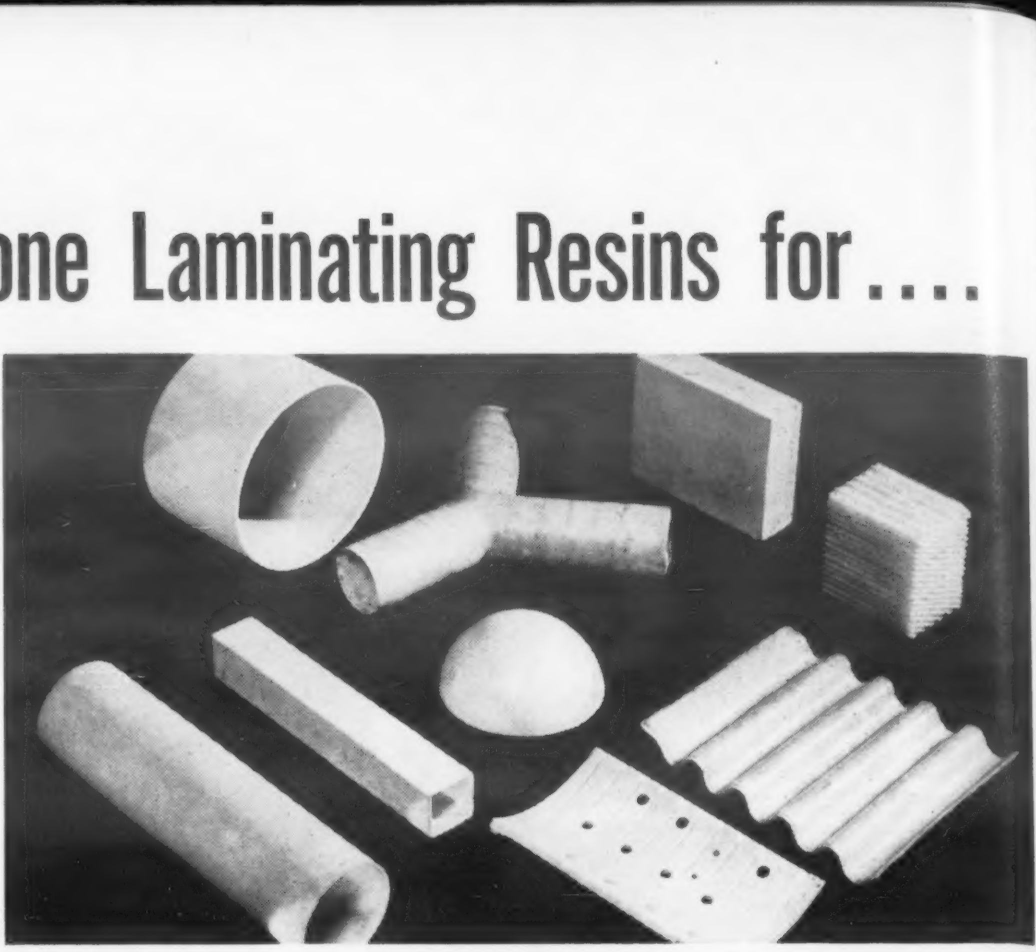
After plating, inspection requirements call for checking the plate for 15 min at 500 F as well as a visual inspection for blisters. The ends of the cases are then joined to the sides with an alcohol rosin flux and a 60-40 lead-tin solder. This seals the mechanisms inside and insures the maintenance of the protective inert gas atmosphere.

# Three New Silicone Laminating Resins for....

● SILICONE FORMULATIONS that are capable of curing to rigid solids have been receiving increased attention in recent months, due to the appearance of new types, and to the need for such materials in fast-flying jet aircraft. Most important in this respect are several resins that can be used with glass cloth to fabricate laminates at low pressures.

The laminates so produced have the heat-resistant properties typical of the silicone family. They are also extremely moisture-resistant, are not attacked by most chemicals, and possess good strength both at low temperatures and at elevated temperatures. Their strength-to-weight ratios at elevated temperatures are superior to those of usable metals, an important consideration in supersonic aircraft. When used in electric motor insulation, they have many times the life of previously available silicone-glass laminates.

The new resins are produced by Dow Corning Corp. and are offered under the designations 2104, 2105, and 2106. Of these, the 2104 material is used for laminates of simple to complex shapes, and for electrical insulation where elevated temperature resistance is of value. The 2105 formulation is especially adapted to electrical insulation, and the 2106 type offers better strength and faster cure, important to structural laminates. In addition to its suitability for low pressure laminating, the 2106 resin has possibilities as a high pressure laminating resin for electrical components.



*Parts made of glass cloth and 2106 grade silicone resin display high strength even after long exposure to elevated temperatures.*

## 1. High Strength

Another resin, intended to have greater physical strength and faster cure, is the 2106 type. Laminates produced with this material also have excellent electrical properties, but it seems destined to win its most important applications in aeronautical and industrial fields. Glass fabric is impregnated with the resin in the conventional manner and precured at about 225 F for 5 min. As with other silicone resins, special release agents should be used when preparing the laminated forms.

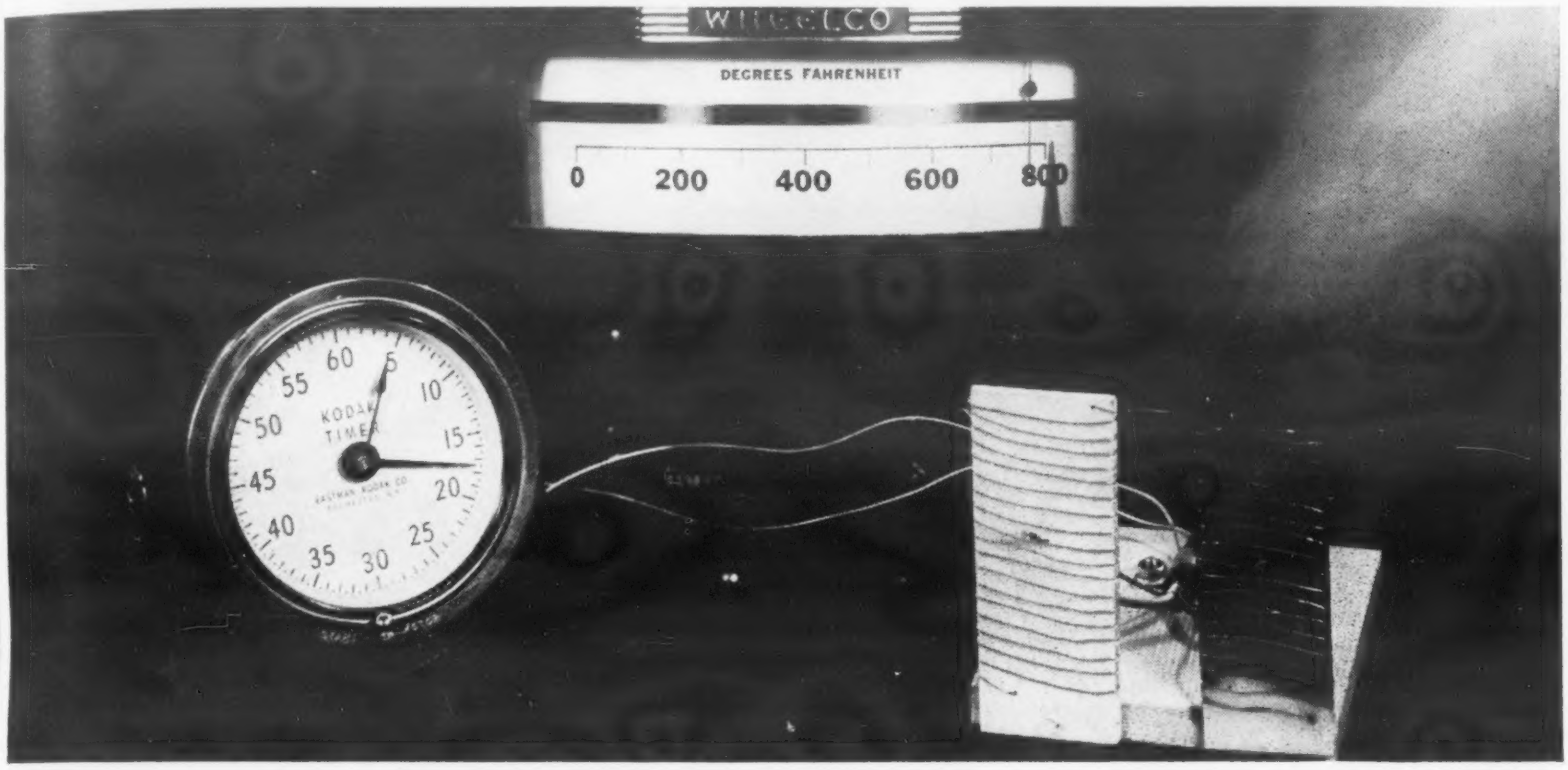
Low pressure laminates of less than ½ in. thickness can be press cured at about 350 F and 30 psi for about ½ hr. The time should be extended to 1 to 3 hr at the same pressure and temperature for laminates of ½ in. or over. Indications are that thin laminates may be removed hot, but the press should be cooled to about 225 F before removing most laminates. An aftercure, consisting of gradually heating the parts to 480 F in an air circulating oven and holding them at that temp-

**Properties of Silicone Glass Laminates Bonded with 2106 Resin (After 48 hr cure at 480 F)**

| | Made With Type 181 Cloth |
|---|---|
| Tensile Strength, psi<br>room temp.<br>at 500 F | <br>40,600<br>30,700 |
| Compressive Strength, psi, room temp. | 21,300 |
| Flexural Strength, psi<br>room temp.<br>at 500 F | <br>50,000<br>18,300 |
| Water Absorption, %, 24-hr immersion | 0.09 |
| Thermal Coefficient of Expansion | $6.06 \times 10^{-6}$ |
| Specific Gravity | 1.93 |
| Arc Resistance, sec. | 244 |
| Dielectric Strength, v per mil | 100 |

erature for 6 hr or longer, is recommended by Dow Corning Corp. *(For further details on 2106 type resin, see Materials & Methods, Feb., 1954, p. 147.)*

The superior strength-to-weight ratios of such low pressure laminates over usable metals suggests their particular value for radomes and similar structures on supersonic aircraft, where skin friction produces a considerable amount of heat.




*Low pressure glass-reinforced laminate bonded with 2104 grade (left test panel) remains unchanged at temperatures approaching 800 F. Conventional organic resin (right) smoked and charred badly.*

# 2. High Temperature Resistance

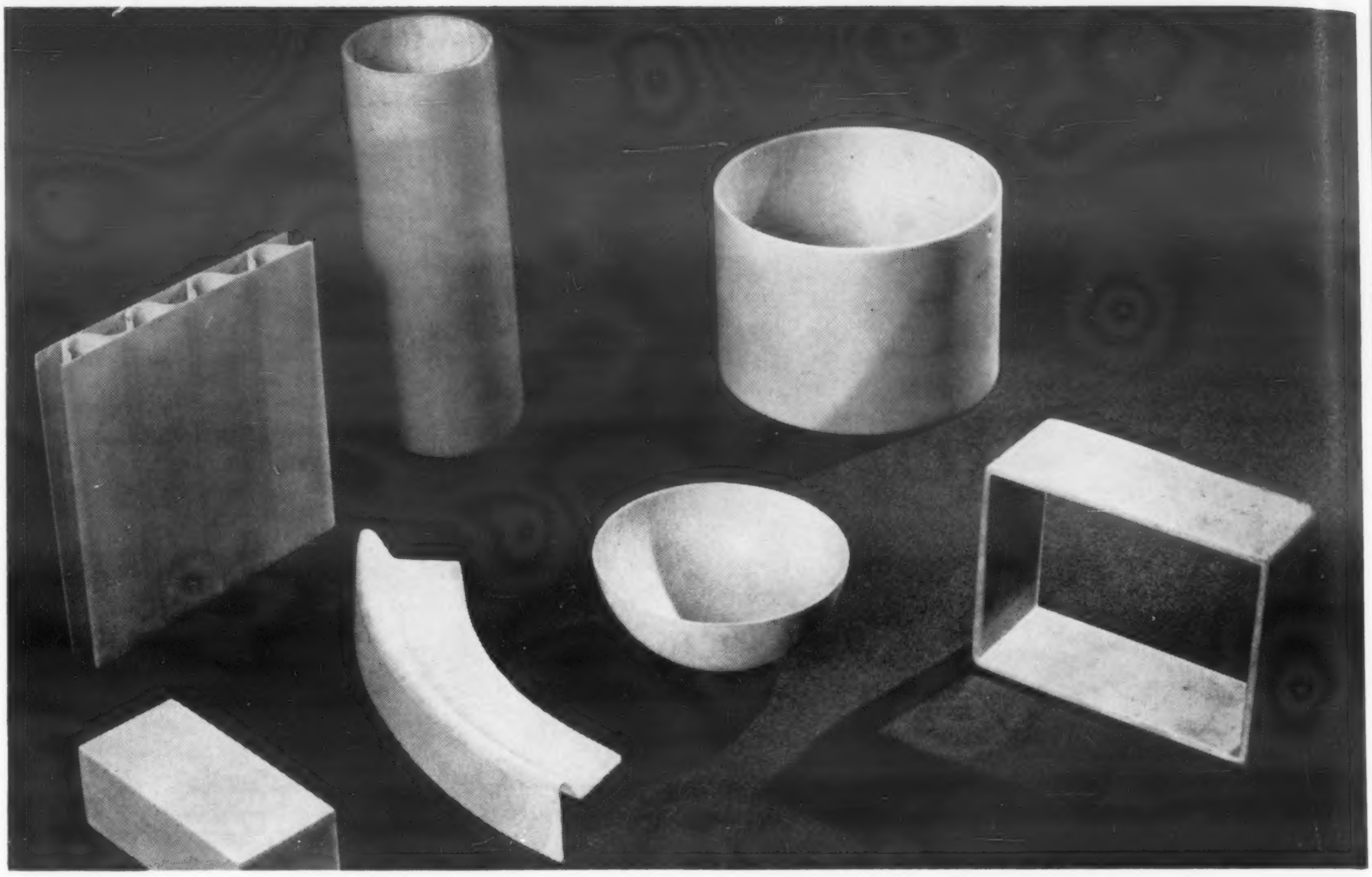
**Properties of Silicone Glass Laminates Bonded with 2104 Resin**

| | |
|---|---|
| Tensile Strength, psi | |
| regular cure | 32,000–36,000 |
| additional high temp. cure at room temp. | 35,000–45,000 |
| at 500 F after ½ hr at 500 F | 22,000–25,000 |
| Compressive Strength, psi | |
| after additional high temp. cure | 17,500 |
| at 400 F after ½ hr at 400 F | 5400 |
| at 500 F after ½ hr at 500 F | 4100 |
| at 600 F after ½ hr at 600 F | 4200 |
| at 700 F after ½ hr at 700 F | 5000 |
| at 800 F after ½ hr at 800 F | 3400 |
| at 900 F after ½ hr at 900 F | 3800 |
| at 1000 F after ½ hr at 1000 F | 4200 |
| Flexural Strength, psi | |
| regular cure, room temp. | 34,000–44,000 |
| regular cure, ½ hr at 500 F | 5500–9000 |
| additional high temp. cure at room temp. | 25,000–35,000 |
| at 400 F after ½ hr at 400 F | 14,000–16,000 |
| at 500 F after ½ hr at 500 F | 12,000–15,000 |
| at 600 F after ½ hr at 600 F | 12,000–15,000 |
| at 700 F after ½ hr at 700 F | 12,000–15,000 |
| at 800 F after ½ hr at 800 F | 11,000–12,000 |
| at 900 F after ½ hr at 900 F | 8000–10,000 |
| at 1000 F after ½ hr at 1000 F | 5000–8500 |
| Impact Str., flatwise, after additional high temp. cure | 25.2 ft. lb per in. of notch |
| Water Absorption, % | |
| after regular cure | less than 0.5% |
| after additional high temp. cure | 1.0–1.3% |
| Specific Gravity | 1.70–1.85 |
| Dielectric Strength, 1/8 in. thick, v per mil | |
| after regular cure | 400 v per mil |
| after additional high temp. cure | 80–100 v per mil |
| Arc Resistance, sec | |
| after regular cure | 300 sec |
| after additional high temp. cure | greater than 350 sec |

Resin 2104 serves for the bonding of glass fibers, mica, or asbestos. It cures to a thermosetting material, but the laminates retain a measure of formability when heated. A catalyst is required with this and the other two silicone resins to complete the cure. The resin is supplied as a 60% solids solution in toluene, and a special catalyst is supplied with the resin. The amount of catalyst required for low pressure laminating differs from the quantity for high pressure laminating.

The laminates are cured ordinarily for 16 hr at 200 F, and 2 hr each at 250, 300, 350, and 390 F. An additional treatment for 140 hr at 480 F may improve properties. Some typical properties of silicone-glass fiber laminate when formed at pressures less than 30 psi are listed in the table.

Laminates made with 2104 resin and inorganic materials meet the requirements of Class H electrical insulation. It is used to bond slot liners and wedges, coil forms, coil separators, etc.



*Low pressure silicone-glass laminates can be made easily in a wide variety of shapes and sizes.*

# 3. Electrical Insulation

Type 2105 resin is especially suitable for electrical applications. The glass cloth-silicone laminate has about 100 times the life expectancy of the former glass-silicone materials in electrical machinery, according to company reports.

Glass cloth for laminating with this resin is impregnated in the usual way, and is then precured for about 10 min at 225 F. Flat laminates are laid up and pressed at 300 to 1500 psi, and 350 F to 480 F is the press temperature range. For a 1/8-in. laminate, cure will be accomplished in about ½ hr at the lower temperature. The press should be cooled to below 210 F before removing the laminate. Curing the laminate for 3 to 6 hr in the press at 480 F eliminates the need for an aftercure. Otherwise, the laminate is postcured in an oven for a period of 16 hr at about 200 F, followed by curing at temperatures gradually increased to 480 F over a period of 14 hr.

While physical and other properties are greatly influenced by such factors as type of resin and glass cloth used, the percentage of resin, and the method of forming and curing the laminate, and the typical properties given in the table are of interest as a guide. Transformer tubes and motor insulation are some of the products for which the material is being used or tested.

**Properties of Silicone Glass Laminates Bonded with 2105 Resin (After 6 hr cure at 480 F)**

| | Made With: | |
|---|---|---|
| | Type 116 Cloth | Type 181 Cloth |
| Flexural Strength, psi, flatwise | | |
| at room temp. | 24,000 | 43,000 |
| at 500 F | 3300 | 4900 |
| Aged 100 hr at 480 F and tested: | | |
| at room temp. | 24,400 | 43,000 |
| at 500 F | 4600 | 8000 |
| Water Absorption, % 24-hr immersion | 0.05 | 0.15 |
| Dielectric Strength, 1/8 in. thickness, v per mil | 310 | 300 |
| Arc Resistance, sec | 260 | 260 |
| Power Factor | | |
| $10^2$ cycles | 0.015 | — |
| $10^5$ cycles | 0.0051 | — |
| Dielectric Strength, 480 F, v per mil | | |
| for 6 hr, v/mil | 300 | — |
| for 5000 hr, v/mil | 180 | — |

# Drawn Shapes from Metal Powders Now Possible

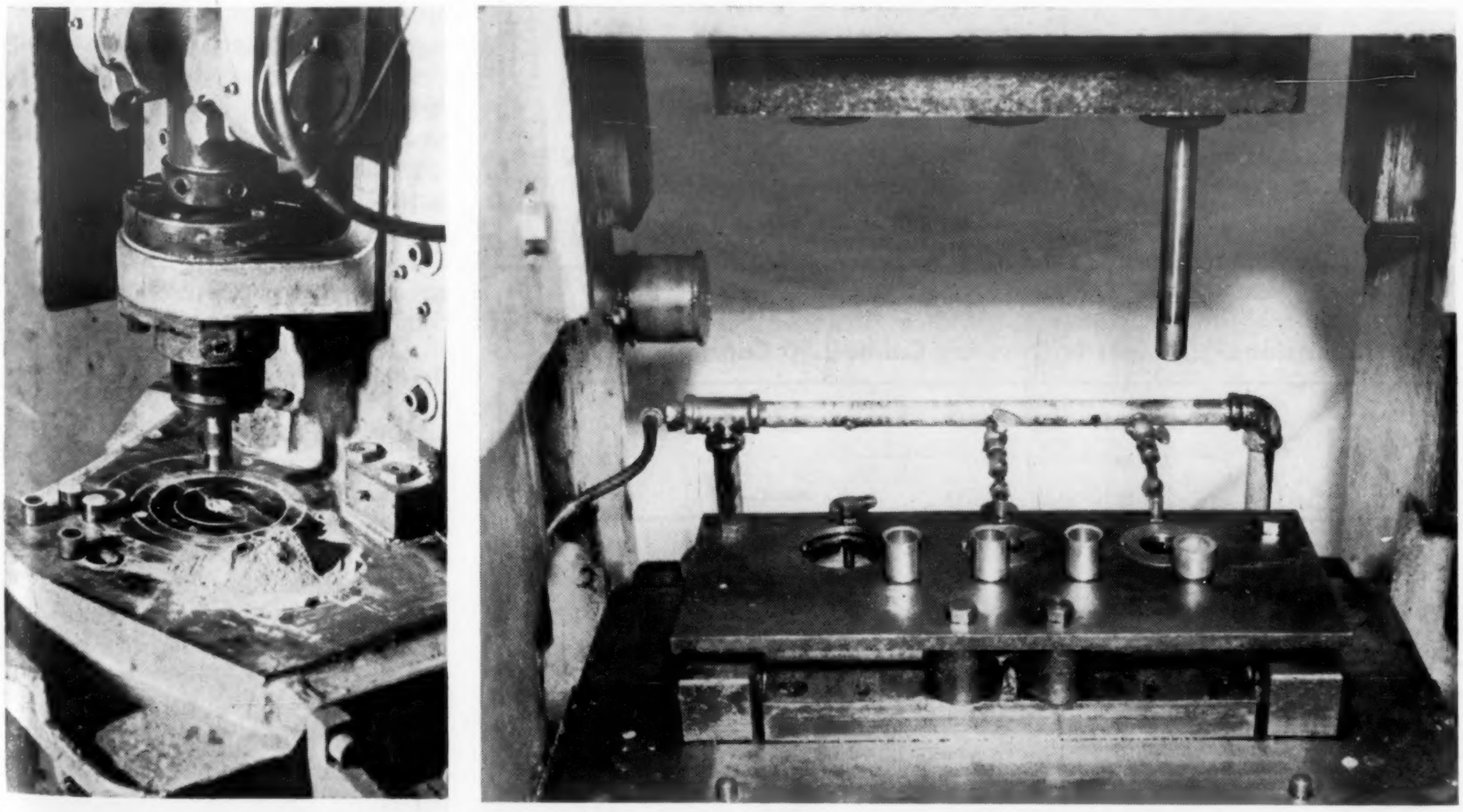
by ROBERT STEINITZ, Research Supervisor and
JOSEPH P. SCANLAN, Project Engineer, American Electro Metal Corp.,
and FRANK I. ZALESKI, Metallurgist, Frankford Arsenal

***Developed primarily for cartridge cases, this new method of making iron powder preforms may open a vast new field of application for metal powders.***

● THE USE OF iron powder as the raw material for cartridge cases has been considered for sometime. However, the thin wall section of the finished case makes it impossible to produce this part directly from powder by the standard methods of pressing, sintering, and repressing. The ratio of height to diameter of the finished piece is also too large for successful pressing. However, it is possible to produce satisfactory preforms, from metal powders, which can be drawn. These preforms are small cups about an inch high and an inch in diameter, which are readily produced by pressing and sintering.

Based on the work done to date, advantages of metal powder drawing preforms appears to be:

1. Eliminates scrap losses associated with blanking stage in conventional blank-cup-and-draw process.
2. Raw material conveniently available from a large number of sources.
3. Raw material has any desired degree of purity and the addition of alloying elements, such as carbon, is possible.
4. Preforms can be molded to the most suitable shape for deep drawing. Base thicknesses of desired values can easily be obtained, thus eliminating the need of moving material into the base during drawing oper-



*Preforms produced by conventional metal powder processes are deep drawn into cups suitable for the production of cartridge cases.*

ations.
5. No blank-cup-anneal operations are required, as with sheet material.

The drawing of these cups represented a problem mainly in the first steps, as the material in the sidewalls densifies to practically 100% density within the first or second draws; in succeeding draws the material behaves very much like wrought material. There is, however, an important difference between the sintered iron and the conventional cup. The material distribution in a sintered iron cup can be varied to any desirable degree by design of the preform. Such is not the case in the deep drawn cup due to the forming limits associated with the cupping of a thick blank. As a result, a considerable amount of material flow towards the base is normally necessary since the head thickness of a finished cartridge case is greater than that of the blank, and therefore, also of the cup. This material flow can be eliminated by the correct design of the preform, which, it is believed, will be helpful in the drawing operation. Of course, it must be understood that this change in the metal flow pattern in the base requires a redesign of the drawing tools.

## Powders Used

The development of the present preform and of its production procedure started with a selection of the iron powder. It was assumed that a considerable reduction in area was essential. It was also recognized that modifications in composition or treatment might be necessary to develop the mechanical properties required for a satisfactory cartridge case. Drawing was easy if the ductility was satisfactory.

Many electrolytic, hydrogen-reduced and carbonyl iron powders and their combinations in various ratios were tried. From these powders, standard tensile bars 0.002 in. thick were pressed. These tensile pieces were produced with a density of 90 to 95% by pressing, sintering, coining, and finally annealing. The tensile strength obtained was, in most cases, over 40,000 psi. The elongation was usually between 20 and 30% and the reduction of area was between 25 and 45%. Mixtures which produced considerably lower values, were rejected. A large number of powders and powder combinations proved to be suitable for the production of preforms. Representative property values are shown in the table. No clear cut superiority of any one kind of powder or powder combination was apparent.

Cups, produced by machining from blanks, were deep drawn. Although, these slugs were machined with different inside radii and different tapers to conform to the shape of the drawing punch, and twenty-two iron powders and combinations were used, no major differences in drawing behavior were detected. These preliminary drawing tests were run to determine the most suitable shape of the preform. Factors such as the height and thickness of the sidewall, the inside and outside radii and the thickness of the base of the cup are exceedingly important and are still being investigated. These shaped slugs could easily be produced to a density of over 90%, and machining presented no problems.

The deep drawing of these preforms, however, was not a simple matter. Numerous lubrication tests were required to determine the most satisfactory type and procedure. During the early work, a five-draw layout was used which had been designed for another material utilizing the blank-cup-and-draw process. However, it was possible to draw a small number of cups into the finished shape through the five drawing steps. This demonstrated that powder metallurgy pieces could be produced with enough ductility and strength to be used as preforms for deep drawing.

## Producing the Preforms

Tools were then designed to produce these preforms by standard powder metallurgical methods without any machining, and to adapt the present coined shape to the drawing requirements. Most of the work was done with hydrogen-reduced iron powder. The addition of a small percentage of carbonyl iron powder was helpful, but was not absolutely necessary. The apparent density of the powder was between 2 and 2.3 g per cc.

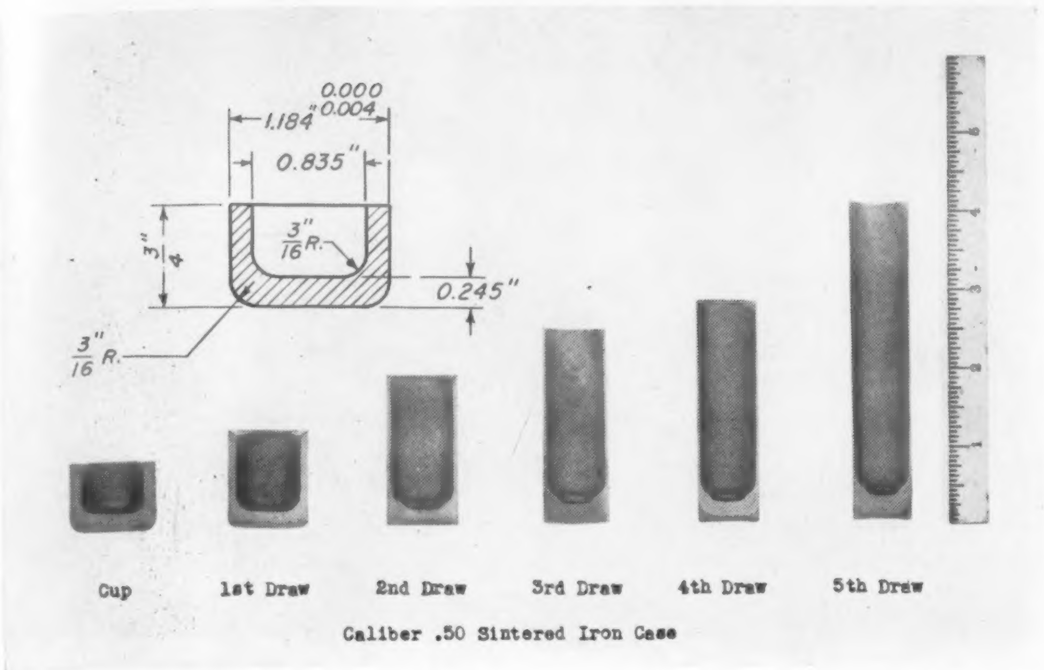
Cups were molded on a mechani-

**Typical Properties of Iron Powder Compacts**

| Iron Powder | Density after Coining, g/cc | Yield Point, psi | Tensile Strength, psi | Elong in 1 in., % | Reduction in Area, % |
|---|---|---|---|---|---|
| Reduced | 7.2 | 23,500 | 43,000 | 23 | 28 |
| Electrolytic | 7.5 | 22,600 | 40,500 | 29 | 39 |
| Carbonyl | 7.5 | 18,700 | 38,500 | 34 | 42 |
| 90% Reduced + 10% Electrolytic | 7.4 | 26,700 | 45,500 | 25 | 28 |
| 90% Reduced + 10% Carbonyl | 7.2 | 23,600 | 41,000 | 27 | 37 |

**Dimensional Changes in Drawing Caliber .50 Cartridge Case**

| Stage | Wall Thickness (inches) | | Percent Reduction in Area | |
|---|---|---|---|---|
| | Mouth | Base | Mouth | Base |
| Cup | 0.1745 | 0.1745 | — | — |
| First Draw | 0.113 | 0.114 | 39.5 | 39.2 |
| Second Draw | 0.0705 | 0.0805 | 40.7 | 33.6 |
| Third Draw | 0.045 | 0.0625 | 40.5 | 28.3 |
| Fourth Draw | 0.026 | 0.0575 | 44.2 | 13.1 |
| Fifth Draw | 0.0155 | 0.052 | 42.4 | 13.2 |




***Cross sections of preform and shapes obtained in various stages in the drawing of cups for cartridge case production.***

cal press to a density of 78 to 80% using Sterotex as the lubricant. These pieces were sintered in hydrogen or cracked ammonia for an hour at 2100 to 2300 F. Slight shrinkage occurred during sintering. Parts were coined in a hydraulic press to a density of over 90%. A mechanical press was used for molding and a hydraulic press for coining, because the first held dimensions accurate while the latter produced a uniform density. The final step was a high temperature anneal at 2300 F, a temperature which seemed to have a beneficial effect on the ductility. An anneal at 2100 F yielded inferior physical properties. The increased ductility may be due to a change in pore shape, as a rounding or spheroidization of the pores seems to occur. No marked shrinkage occurred.

## Deep Drawing the Preforms

For deep drawing, the cups were copper plated by the Cuprodine process, the copper acting as a lubricant between the piece and the drawing punches and dies. Various lubricants were tried for these cups, but it is difficult to make a definite recommendation because changes in a draw layout and variations in density of the coined preform will influence the selection of the lubricant. In some cases, a heavy soap solution, in addition to the copper plating, helped appreciably to obtain sound draw pieces.

Steps in deep drawing and the reductions in cross-sectional area of the wall are shown in accompanying figures. The material for ironing is taken essentially from the walls of the cup while the base material remains little affected. Design of both preform and tooling are important to achieve this effect. No cupping operation is required, as is necessary with sheet material, and the fact that the iron cup is slightly porous helps to adjust it to the punch and die in the first draw setup. The sidewall is 100% dense in the remaining drawing stages. Thickness of the base after the final draw piece can be selected at will.

The density of the cup should be uniform for the wall as well as for the base material. This can be obtained by the correct adjustment of the coining die which makes it possible to correct the density variations resulting from molding. In the molded cup, the base is usually somewhat less dense than the wall. The drawing die is of conventional design, however, the entrance angle must be changed to adjust for the difference in material flow and to eliminate or minimize doming. A fast acting mechanical press is used.

Failures in drawing usually occur at the junction of base and sidewall as large or small circumferential cracks. Blending the two sections of the cup together by correct inside and outside radii and design of the drawing tools which permits the required flow of material, insure the production of satisfactory final draw pieces.

Several final draw pieces have been processed through the remaining stages into finished cartridge cases; however, they were not processed into complete rounds and fired.

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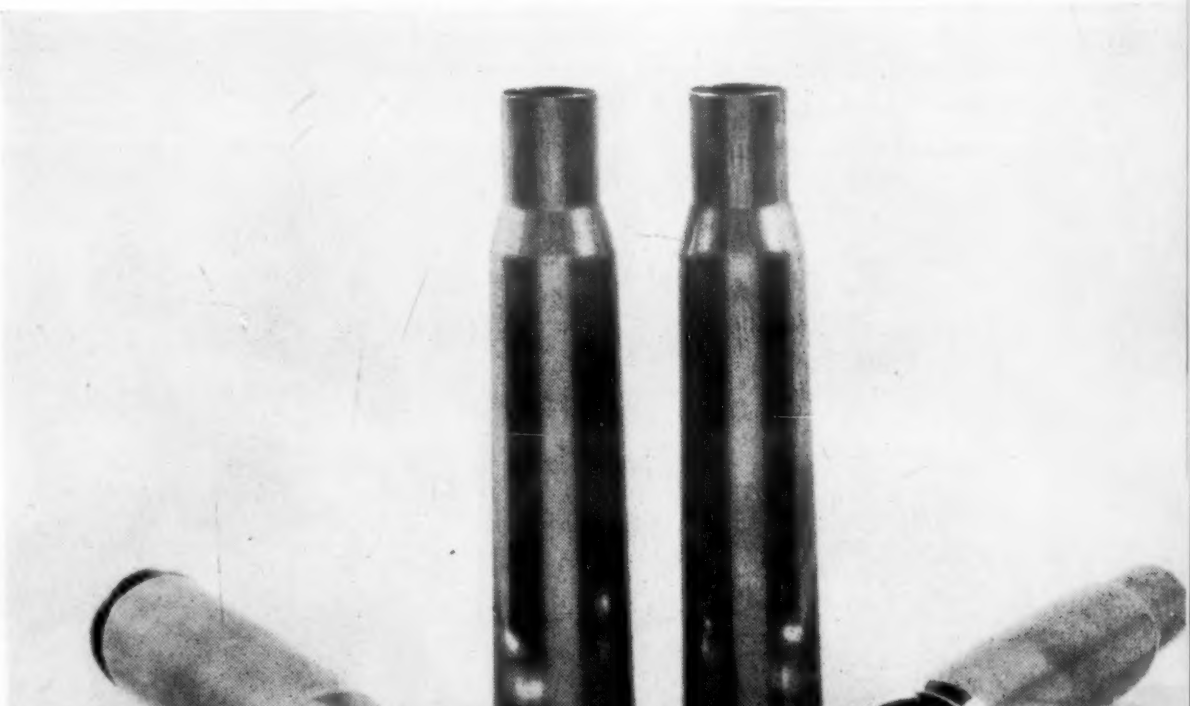
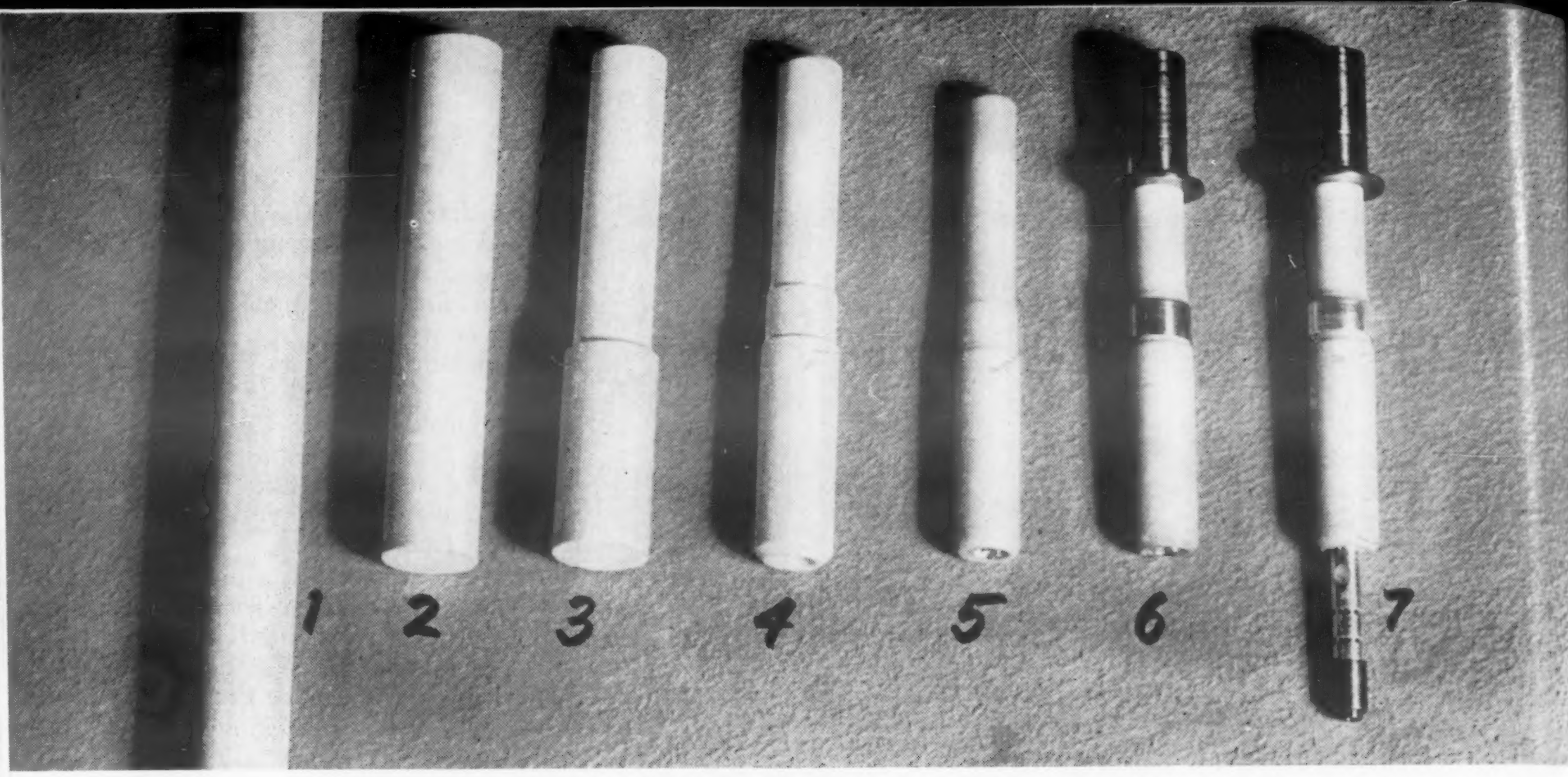
This article was adapted from a paper presented at the annual meeting of the Metal Powder Association, April, 1954.



***Caliber .50 cartridge cases produced from iron powder.***



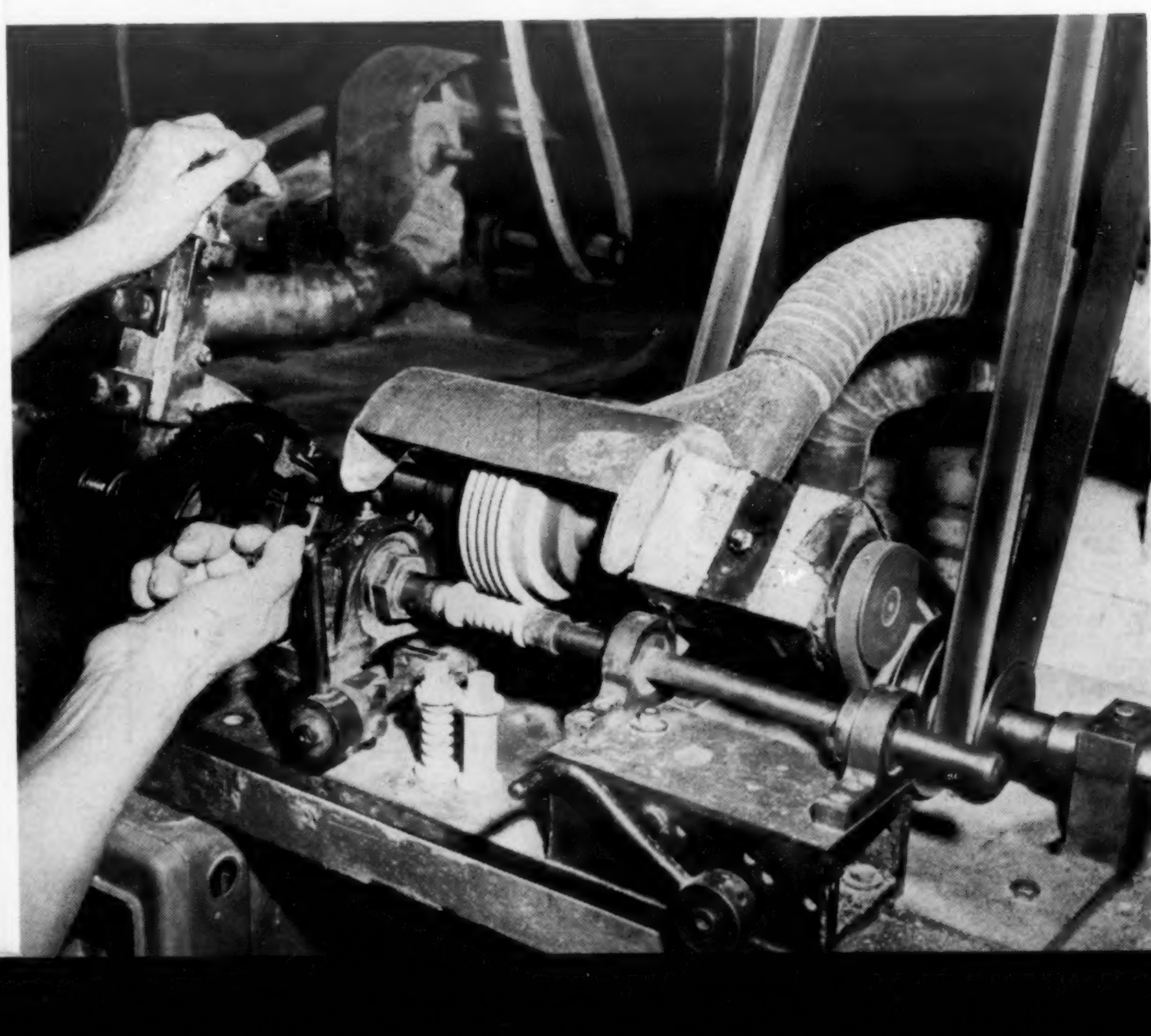

*Various stages in forming a ceramic tuner capacitor shaft at American Lava Corp. 1—Unfired rod from which tuner shaft is cut. 2—Shaft cut to length. 3—Shaft ground over outside diameter. 4—Shaft ground in centerless grinder. 5—After firing (note shrinkage). 6—Metal arbor and band added. 7—Metal shaft inserted to complete piece.*

# How To Form and Finish Ceramics and Glass

**by KENNETH ROSE, Mid-Western Editor, Materials & Methods**

***The only practical method of changing the form, and refining the dimensions or finish of these hard vitrified materials is with abrasives. Many different abrasive techniques are now in use.***

*Ceramic heater core being threaded using a formed wheel on a special machine at American Lava Corp.*



● FOR MOST MATERIALS used in industry, there is a range of fabricating methods available. However, the ceramic materials, including porcelains, steatites, and glass are somewhat limited as to formability. Glass can be hot-formed, and the clay bodies can be cold molded before firing. All are so hard as to be practically non-machinable with cutting tools, and their perfect elasticity up to the ultimate strength of the material makes cold pressing or drawing impossible. After the clay bodies have been fired, the only practical means of changing form or refining dimensions or finish is with abrasives, and the same is nearly the case for glass.

Abrasive forming, then, is of more importance with the ceramics than with other materials, hard or soft. In addition to surface grinding, internal and external, it properly includes sawing and some kinds of drilling. Sawing is done with bonded abrasive wheels, or with abrasive-charged metal disks. Frequently in drilling, an abrasive powder is used with the drill, and, in such cases, the abrasive is the real cutting agent. Some cutting can be done with carbide cutting tools or with diamond tools.

The possibilities of abrasive forming take on a new interest as demands increase for ceramic parts produced to close tolerances. It was shortly before World War II that the radio and electronics industries began to demand porcelain parts made to high precision. The television industry, expanding in the postwar years, also required ceramic insulators made to a precision not possible in ordinary fired ware, and grinding of the hard material became a necessity.

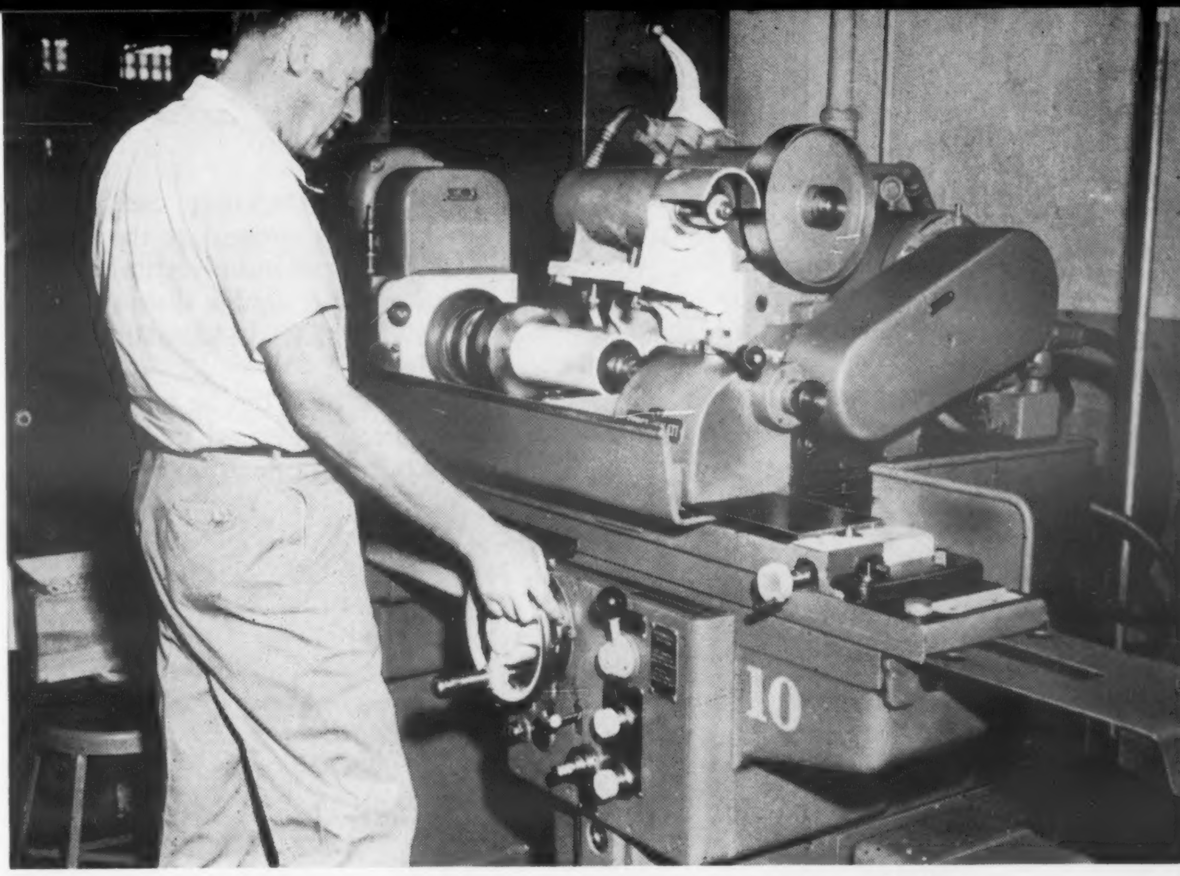
## Forming Unfired Parts

There are two steps in the forming of these vitrified materials. The basic shape is first produced by pressing, extruding, machining, or casting. Before firing, the formed piece is regarded as free machining, and it may be cut without difficulty by ordinary metal cutting tools. Even the unfired material is quite abrasive, however, and carbide tools are recommended for high production. The unfired body may be drilled, tapped, or turned by carbide tools.

Abrasive forming is useful in the processing of the unfired ceramic bodies also. Silicon carbide abrasive wheels, resin bonded, of about 70 grit, are excellent for sawing and cutoff. Alundum wheels also give excellent results. Used in a medium hardness grade, the wheel does not load nor glaze when cutting through the unfired ceramic. A cut-off wheel of this type, 8 x 1/16 x 7/8 in., has cut as many as 7000 tubes of 1/4-in. o.d. per hour.

External threads are cut on ceramic bodies before firing when possible. The threads are ground to full depth in one pass. In form grinding, milling, and slotting unfired parts, it is usually economical to press the piece to a partial or rough shape, and to finish in a second operation. This keeps wheel wear low. In a typical operation, a groove in an oven support is first pressed, then ground with an 8 x 3/8 x 7/8-in. wheel. Two wheels in a special machine turn out 8000 to 10,000 pieces per hour, and require only one or two dressings per 24-hour day, to sharpen and unload them.

There is no corresponding unfired state in the production of glass. After the ingredients are fused and become "plain", the glass is formed in molds or by free blowing, and is then usually in the finished state except for sawing, drilling, or similar minor operations.




Grinding ceramic inductance form at American Lava Corp. using a diamond wheel.

Expert workmen at Pittsburgh Plate Glass Co. plant spot polish large plate of glass on scratch wheel.

## Forming Fired Bodies

Hot operations on glass and clay bodies are incapable of producing parts to precise dimensions or having accurate surfaces. A tolerance of about plus or minus 1% is required on fired bodies. The vitrified material must be formed cold; surface refinement must be performed after firing; accurately located holes must be drilled in the fired piece, or whatever precise positioning or sizing is required by the design must be done on the hard, abrasive material. It is here that abrasive forming is of major importance.

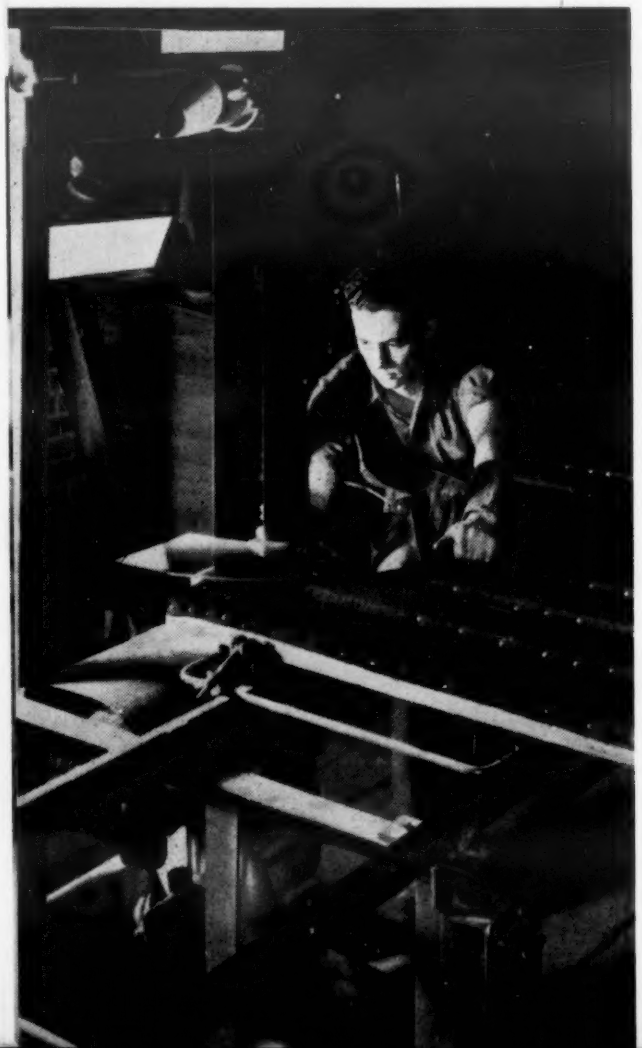
While the hardness of unfired ceramic bodies is of the order of 1 or 2 on Mohs scale, the fired bodies have a hardness varying from 6 to 9. Specifications frequently require that

this hard material be finished to a tolerance of 0.0001 in. It is because of such requirements that, whereas few fired ceramics were ground twenty years ago, the grinding department is frequently one of the largest in the modern ceramics plant.

Parts up to about 4 sq. in. in area can be ground flat on two sides to a tolerance of 0.0001 in. in flatness, to 0.0005 in. in parallelism, and to

**A battery of grinding and polishing disks. Glass is ground to uniform thickness, then polished. (Pittsburgh Plate Glass Co.)**

***Abrasive belt is used to finish edge of curved cut-out on half circle of plate glass. (Pittsburgh Plate Glass Co.)***



0.0001 in. in thickness. Small pieces can be finish ground at the rate of 2000 pieces per hr on vertical or horizontal spindle, double disk machines. Wheels to 23 in. in diameter are popular.

Ceramic parts can be lapped flat to an accuracy measured in light bands by 500-grit lapp-flour on conventional machines. For special shapes on single spindle horizontal and vertical surface grinders, diamond wheels are usually required. A 100-grit diamond vitrified wheel gives maximum stock removal with minimum wear. Such wheels are more expensive, due to the higher wheel costs and to the special handling and cleaning of finished parts, but are necessary for the surface quality and accuracy required for some purposes. A wheel 20-in. in diameter and having 6-in. face bonded with industrial diamonds has been installed at American Lava Corp. for high speed grinding of hard ceramics. The wheel lists at $25,000. Long production runs to a tolerance of 0.0001 in. are possible.

There has been a distinct rise in the demand for alumina ceramics, which have a hardness of 9 on Mohs scale. Much of this production is also required to be finished to close tolerances. For this, diamond wheels must be used, and preferably the metal bonded types. In general, the size of the diamond particles determines the finish in micro-inches. While no specific size-finish rating is possible, a grit of 100-S will produce a finish of the order of 60 to 70 micro-inches. The lubricant used, the nature of the material being ground, and the kind of machine tool used will enter into the results obtained.

Centerless grinding is much used for finishing rods and tubes. These are ground to a tolerance of plus or minus 0.0001 in., using silicon carbide wheels of from 80 to 600 grit. Tubes and rods of alumina must be ground with a diamond wheel.

Ceramics not being magnetic, cannot be held in a magnetic chuck as are the ferrous metals when being surfaces ground. The ceramics are held in wax on the chuck plate. External grinding of ceramics is performed with both silicon carbide and diamond wheels. Internal grinding is accomplished with diamond wheels, and internal cutting with mounted diamond points. Internal surfaces are also honed with diamond honing stones. When fired ceramics are to be cut to high precision, diamond saws are used.

It is very uneconomical to use a fine grit wheel to remove stock in the early stages of grinding. Production of a fine finish is best done in several steps, using a progressively finer grade of abrasive for each step.

Glass, with a hardnesss of about 5 to 7 on Mohs scale, can be cut by Alundum or silicon carbide wheels, and for short runs, by metallic carbide tools in some cases. Carbide drills are used regularly to drill glass, and hold up well for runs of a few hundred pieces, Longer runs are more economically done with synthetic abrasives, or with diamond tools.

A new technique that is sometimes used for drilling glass is ultrasonic grinding. In this process, a mandrel is coated with a small amount of a powdered abrasive, and vibrated very rapidly in a quill by an ultrasonic unit. The process is intended for production of small holes and abrading of small areas only; the mandrels used are usually less than $\frac{1}{4}$ in. in diameter.

The largest use of grinding in the processing of ceramics is in the grinding of plate glass. The rough glass from which plate glass is made, commonly has an embossed pattern over its surface to permit the abrasive to get a quicker start. Huge wheels, often 8 ft or more in diameter, are studded with grinding blocks of steel, and a fine garnet abrasive suspended in water is fed to the surface of the plate to do the actual cutting. After a final grinding with a fine abrasive, such as sand and emery, the glass goes to the polishing line where huge horizontal wheels much like the grinding wheels, but covered with felt and using "rouge" or fine ferric oxide, as the polishing powder, finish the surface of the plate.

An important development in the grinding and polishing of plate glass is the use of twin-grinding, in which the plate moves between two horizontal abrasive wheels and is simultaneously ground on both sides. This is reputed to improve both the speed of grinding and the precision of the work.

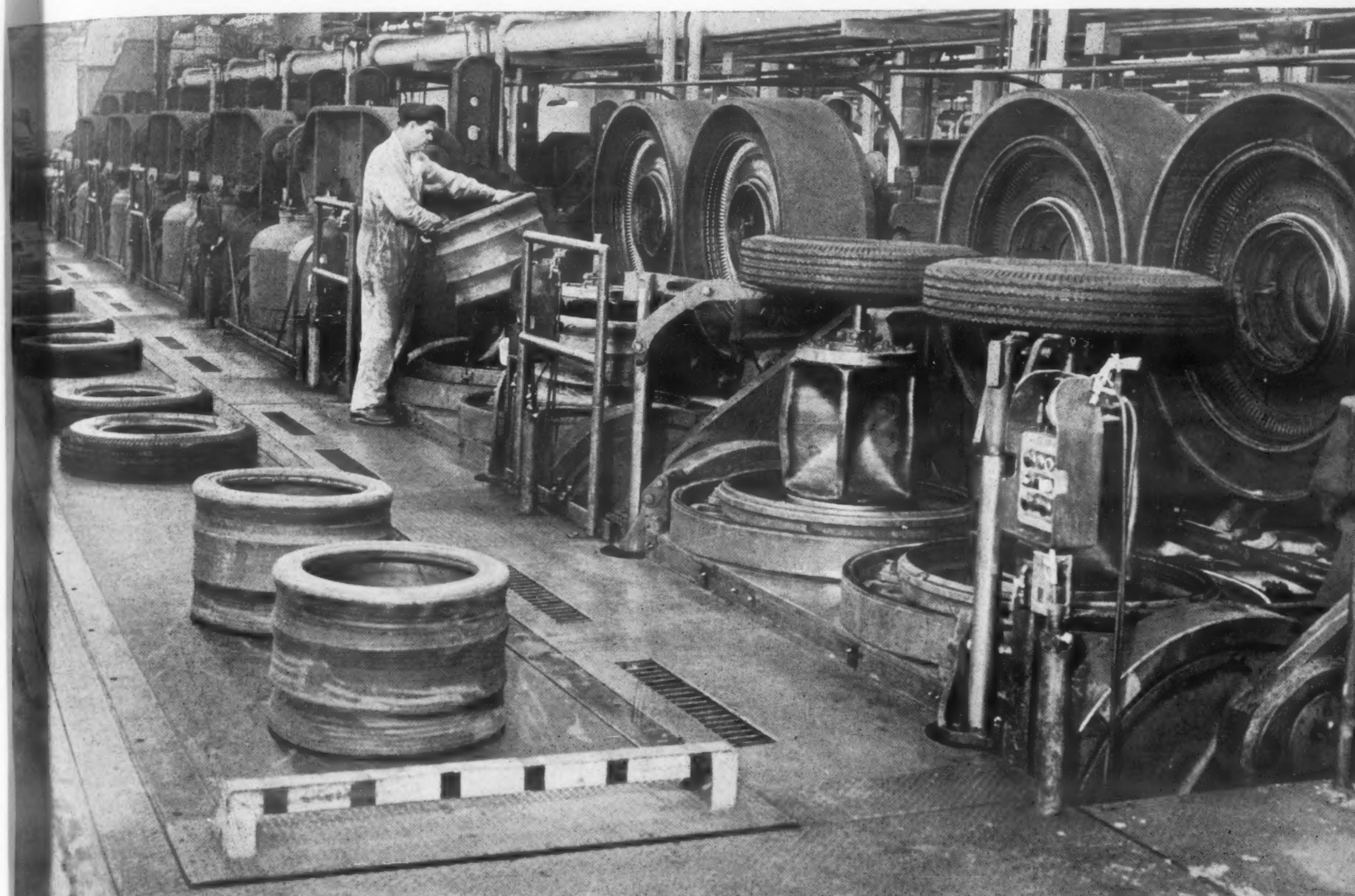
Abrasive belts are used for finishing contours in glass. Silicon carbide grains of about 60-grit size on a waterproof cloth belt moving at about 4000 surface ft per min are typical of this practice. Water is used as the coolant. Other abrasives can be used also. Bevels on counter tops, mirrors, table tops, etc., may be ground on a smaller wheel, then polished in the same manner as the larger surfaces.

# Materials at Work

***Here is materials engineering in action . . .***

***New materials in their intended uses . . .***

***Older, basic materials in new applications . . .***

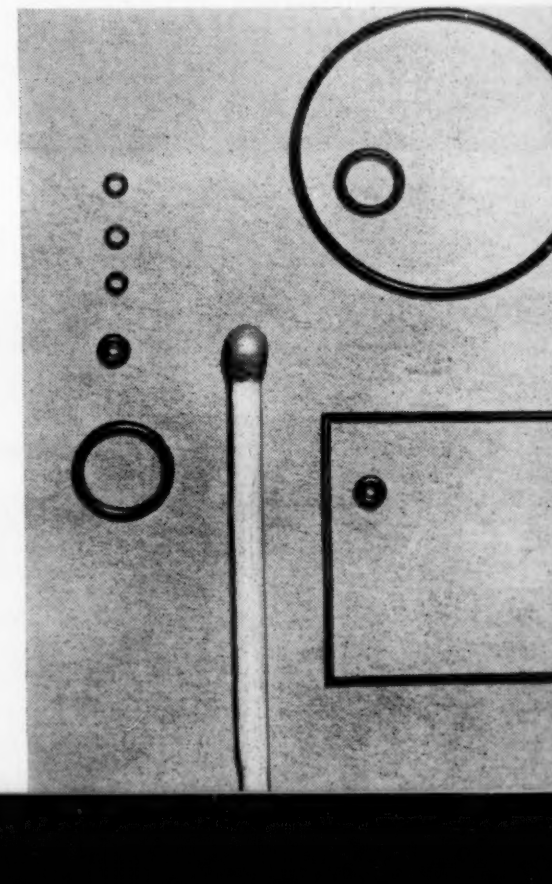


**Rubber on Rubber** A moving rubber sidewalk, installed flush with the ground floor level of the B. F. Goodrich Co. plant at Miami, Okla., feeds "green" tires to the line of vulcanizing presses and carries away the "cooked" tires to final inspection.

There are now four 48-in-wide conveyor belts located in front of parallel lines of presses. The four belts empty the finished tires onto a fifth belt which carries them to an inspection point where the final trimming is done. Over-all length of the belt installation is 1148 ft.

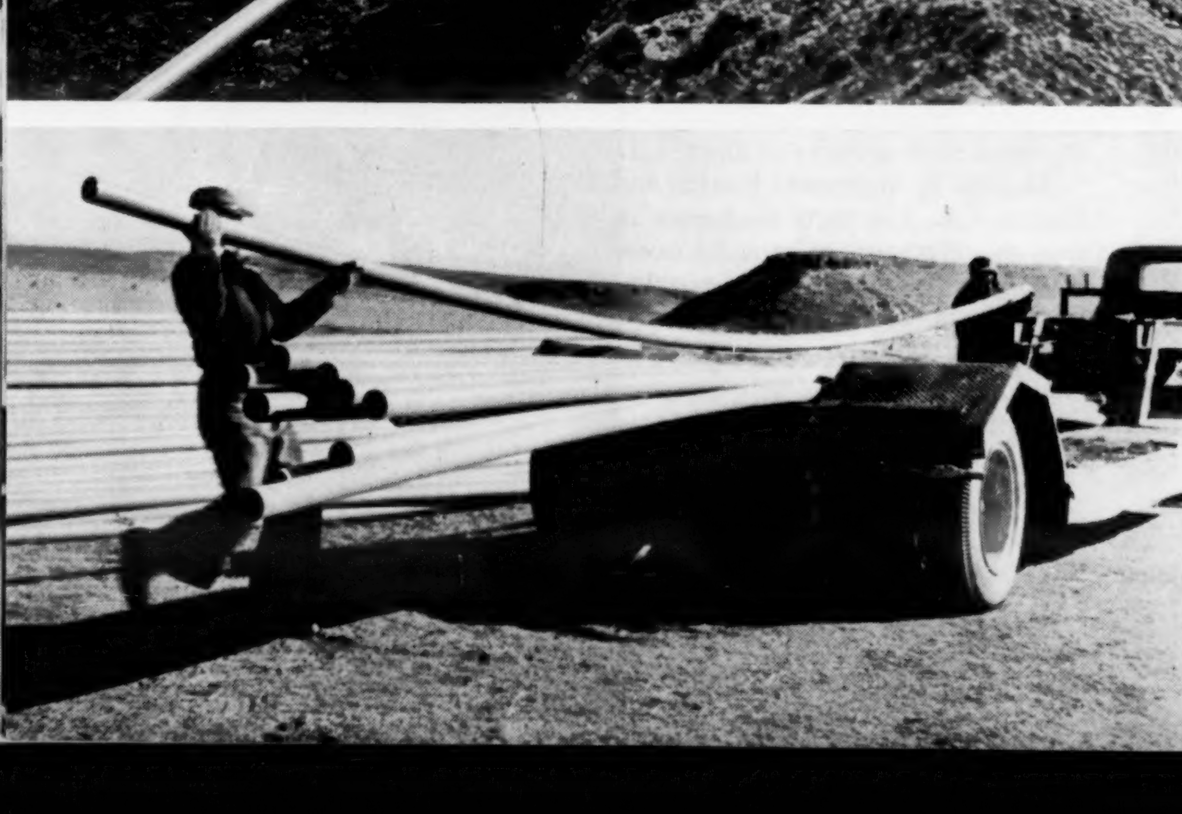
**Tiny Rubber Parts** The injection molding process is used to form these sub-miniature O-rings, and other tiny rubber parts. They are available in sizes as small as 0.010 in. cross section and 0.020 in. i.d.

Molded by Minnesota Rubber and Gasket Co., the parts find uses in the manufacture of watch cases, water injection carburetor nozzles, micro switches and miniature air valves and controls.



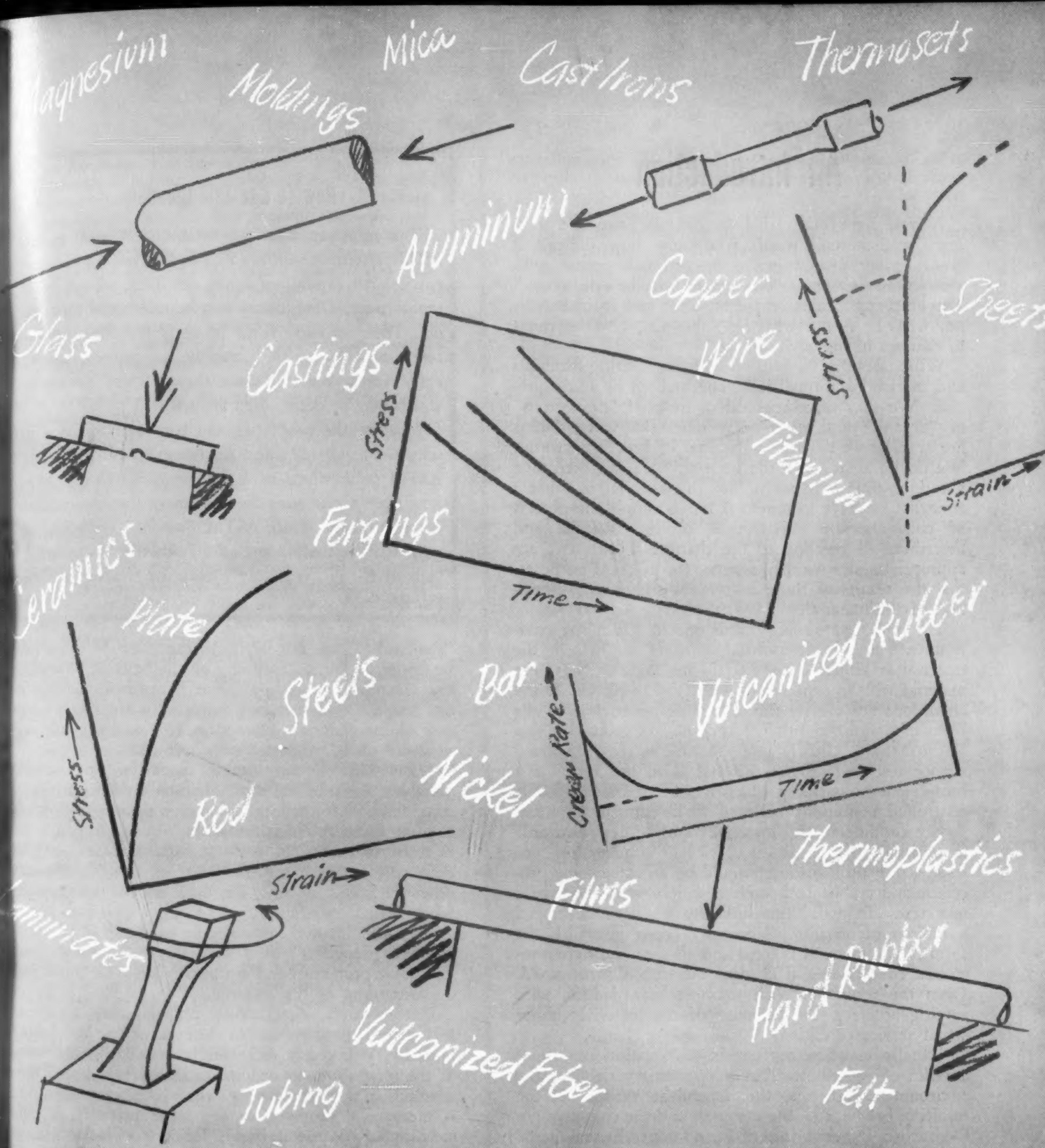
**Steel Carpet Roller** A workman is putting the finishing touches to the face of a 28-ton jacketed steel drier roll, built by Lukenweld, Div. of Lukens Steel Co.

The roll is 8 ft in diameter, 19 ft long, and will be used by the C. H. Masland Co. to press and dry broadloom carpet in the final step of their rug-making process. The jacket is made of ASTM A 385 Grade C carbon steel; the outer skin is 1⅜ in. thick while the inner is ⅞ in.



**Plastics on the Plains** Shown here, in part, is an installation of rigid vinyl pipe, over three miles long, installed last December on the Kansas plains. The pipe, manufactured by the Southwestern Plastic Pipe Co., carries salt water separated from crude oil to deep disposal wells.

Under Kansas law all salt water obtained from oil production must be returned deep enough into the ground to prevent contamination of any surface water. With the aid of heat and various chemicals, an emulsion treater separates the gas, oil and salt water. The salt water is then channeled into the pipe made of B. F. Goodrich Chemical Co.'s high impact Geon resin. It is light weight for ease in handling, flexible, reducing the amount of ditch-grading required, and will not corrode under contact with the salt water.





**MATERIALS & METHODS**

**Manual No. 106**


**This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and applications.**


JULY 1954


***A comprehensive compilation of terms representing the most important***

# Mechanical Properties and Tests

***of the common engineering materials.***
***This glossary has been designed to give to engineers and designers a brief, easily visualized picture of the true meaning of each property, namely the test by which it is determined***


**Compiled by JOHN B. CAMPBELL, Associate Editor, Materials & Methods**

# An Introduction

If you have ever tried to describe someone in a few "well-chosen" words you know how difficult it is to convey a meaningful image of a person with abstract words such as "he's honest" or "he's dishonest." The best way to make a person seem real is to describe not what he *is* but what he *does*—i.e., how he reacts to changes in his environment.

What does this have to do with engineering materials and mechanical properties? The analogy is fairly precise. We may sometimes call a material "nonferrous" or "organic" and let it go at that. But when dollars are at stake we describe a material by how it performs. We devise a "test" in the hope that we can determine ahead of time whether or not the material is suitable for what we have in mind. A test is simply the process of changing the environment of the material and describing its reaction to the change. If our tests are appropriate ones we may assume, for practical purposes, that the results of those tests are a significant description of the material.

The most appropriate test is one in which the environment and environmental changes to which the material is subjected are exactly the same as those the material will be expected to withstand in service. If the conditions are exactly the same, the material is in the form of a finished product and the test is known as a "service test". Usually more feasible is the "simulated service test" where the material is in the form of a component or assembly which is subjected to artificially controlled conditions believed to be similar to actual service conditions. If a material could be described only in terms of the results of service or simulated service tests, sizing up a material would be a cumbersome procedure indeed. In fact, each new job would require a new test. To avoid this difficulty we have developed a limited number of "laboratory" tests in which the form of the material is fixed and all significant environmental conditions and changes are carefully measured. From the results of such tests we may deduce, with varying accuracy, the behavior of the materials under actual service conditions.

Actually, a laboratory test is an equation or, often, a series of equations. The independent variable is the environmental change, the dependent variable is the resulting behavior of the material, and the constants are the unchanging environmental conditions. In some tests, including most tests used for control or acceptance purposes, a single value is assigned to the independent variable and the dependent variable determined. In other tests, such as the tension test, the value of the dependent variable is determined for each of several values of the independent variable, thus showing the effect of change. In still other tests, such as the creep test, two or more independent variables may be changed, one at a time, in order to show the effects of changes in each upon the value of the dependent variable. However complex the test, if the independent variable and the constants are specified, the dependent variable becomes a "property" of the material.

A series of equations is an unwieldy tool. After some experience we find that certain fixed values for the constants and even, sometimes, for the independent variable, seem to be more significant than others. We "standardize" the test by restricting the values that may be assigned. Then, depending on the latitude allowed by the "standard procedure", the dependent variable or test result, alone, may be considered a significant property of the material. This is the true and the only significance of a "property" of a material.

Many different measurable quantities may be test variables. Some of the most common are time, temperature, load, deformation, voltage, weight loss and ion concentration. A "mechanical test" is one in which the material is loaded in some manner and load and/or deformation are among the variables. Usually, the only other variables, if any, are time and/or temperature. Since virtually all fabrication processes and most service applications involve some degree of loading, the "mechanical properties" of a material are often its most important properties and are usually basic for a practical understanding of the material.

Unfortunately, a mechanical property that is more or less standardized tends to lose some of its proper humility. It becomes increasingly associated with some of the most common deductions made from it and thus develops a new personality which obscures its origin. A mechanical property, or any other property, is only meaningful because it stands for a specific mechanical test. The only true definition of a mechanical property is a description of the test by which it is obtained. The present article is called a "glossary" because, although the entries for properties are somewhat extensive, they correspond to definitions in the sense discussed here.

This glossary has not been assembled for laboratory personnel, nor does it attempt to describe in any detail the various deductions concerning fabrication and service commonly associated with a mechanical property. Space limitations have also made it impossible to include information on all significant testing constants and variables (such as conditioning procedure and testing direction) or on the proper statistical interpretation of test results. The sole purpose has been to provide in convenient reference form, a brief, easily visualized picture of the true meaning of each of the most important mechanical properties.

## How To Use This Glossary

This glossary lists properties, tests and a few auxiliary terms essential to an understanding of other entries. All capitalized terms are listed separately in the glossary. The glossary is cross-referenced throughout. Thus, an entry for a property indicates the different tests by which it may be determined, and an entry for a test indicates the different properties which may be determined from it.

Most of the properties and tests are discussed in standard handbooks, and references to corresponding ASTM publications have been included in this glossary. Such a reference does not mean that the method described here is an ASTM Standard method, but only that related information, whether "standard", "tentative" or "advisory", may be found in that reference.

**Alpha Rockwell Hardness**
A measure of Indentation Hardness of Plastics. An index of resistance to surface penetration by a specified indentor under specified load obtained with the Rockwell Hardness tester (D785-51). A higher Alpha Rockwell Hardness indicates a higher Indentation Hardness. The spring constant of machine and indentor is determined by a special procedure. A 10-kg minor load is applied to the ½-in. ball indentor and the dial deflection gage zeroed. A 60-kg major load is applied and number of scale divisions passed by the dial pointer in 15 sec observed. This figure minus the number of scale divisions equivalent to the spring constant represents total indentation under load. Alpha Rockwell Hardness is calculated by substracting this net number of scale divisions from 150.

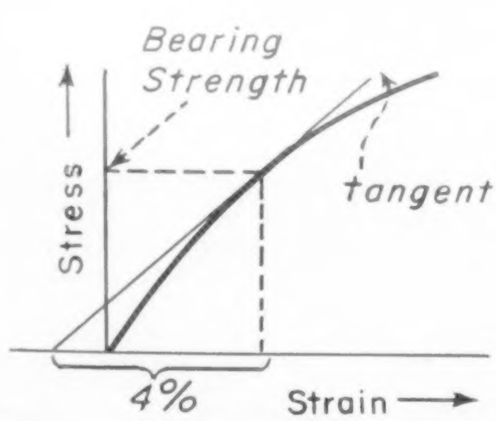
**Angle of Bend**
See *Bend Angle* and *Bend Angle, Maximum.*

**Angle of Twist, Permanent**
See *Torsional Deformation, Permanent.*

**ASTM Hardness**
A measure of Indentation Hardness of rubber. The depth of penetration of a 0.0938-in. dia hemispherical indentor acting under a 3-lb load and through an annular presser foot which itself is under a 5-lb load. Presser foot load is applied first. The indentor is then brought into contact with the rubber surface, the load applied without shock, and indentor penetration in mils beyond the presser foot observed after 30 sec of loading. A lower ASTM Hardness indicates a higher Indentation Hardness. The test is most suitable for rubbers that are not extremely hard or soft. ASTM Hardness (D314-52T) differs from Pusey and Jones Indentation in that the latter involves free plastic flow about the indentation whereas this method involves precompression of the rubber adjacent to the indentation.

**Bearing Stiffness**
A measure of stiffness of a material subjected to a bearing load. For plastics it is the slope (psi) of the straight-line portion of the Stress-Strain curve obtained in the Bearing Strength Test. By definition: Bearing Strength multiplied by 25.

**Bearing Strength**
A measure of the maximum usable bearing stress that can be developed in a material. For plastics it is the stress at the point on the Stress-Strain curve obtained in the Bearing Strength Test where slope of the curve is equal to that




stress divided by a strain of 4%. This point can be determined by trial-and-error or, more readily, by means of a superimposed transparent template.

**Bearing Strength Test**
A method of determining the behavior of materials subjected to edgewise loads such as those applied by mechanical fasteners. For plastics (D953-48T), a flat rectangular specimen with a bearing hole centrally located near one end is loaded gradually either in tension (Procedure A) or compression (Procedure B). Load and longitudinal deformation of the hole are measured frequently or continuously to rupture and resulting data plotted as a Stress-Strain Diagram. For this purpose, Strain is calculated by dividing change in hole diameter in direction of loading by original hole diameter. Bearing Stress is calculated by dividing load by bearing area, bearing area being equal to the product of original hole diameter and specimen thickness. Properties determined from test and diagram include Bearing Strength, Bearing Stiffness and Maximum Bearing Stress. Test results are influenced by "edge-distance ratio", which is the ratio between distance from center of the hole to nearest edge of the specimen in the longitudinal direction and hole diameter.

**Bearing Stress, Maximum**
The maximum nominal stress developed by a material in the Bearing Strength Test. It is calculated by dividing rupture load by original bearing area.

**Bend Angle**
A measure of Bendability. The angle through which a material is bent under specified loading conditions in a standard Bend Test.

**Bend Angle, Maximum**
A measure of Bendability. The largest angle through which a material can be bent under specified conditions in a Bend Test without failure. It may be either angle at failure or angle at which first indications of failure are observed.

**Bend Elongation**
A measure of Bendability. The Elongation of the outer surface in the bending region of a material at the conclusion of a Bend Test as determined either by gage length measurement or by computation based on radius of bend.

**Bend Energy**
A measure of Bendability. The energy absorbed by a material in bending through a specified angle or to failure. It may be determined only when loading conditions are measured, as in the standard Bend Test for electrical resistance wire. In this test, Bend Energy is calculated as follows:

$$E = M R \sin \theta$$

where $E$ = Energy Absorption in bending, in.-lb
$M$ = weight, lb
$R$ = distance from axis of rotation to center of gravity of loading system, in.
$\theta$ = Bend Angle

**Bend Radius, Minimum**
A measure of Bendability. The smallest radius around which a material can be bent a specified angle in a Bend Test without failure.

**Bend Test**
A method of determining Bendability and related properties. Many different tests are used and few are widely standardized. Most can be classified as either "free" or "restricted" as follows:

In free bending, the bar or rod specimen is freely supported at two points and a bending load is applied at the center of the span or, alternatively, at two points which divide the span into three equal segments. The specimen is bent 5-30 deg. It is then squeezed between parallel jaws until doubled over or until rupture occurs. Bendability is expressed as Maximum Bend Angle or as Bend Elongation (E16-39).

In restricted bending, the specimen is bent around a pin, mandrel or die. Bendability is expressed as Maximum Bend Angle for a specified radius, as Bend Elongation, or as Minimum Bend Radius for a specified angle. The last is the criterion of Bendability in a standard test for compressed asbestos sheet packing (D733-53T) in which a 1-in. wide strip is bent 180 deg.

Another standard test is used to determine the temper of round or rectangular electrical resistance wire (B113-41). The wire is clamped rigidly at one end and a beam-supported bending die is brought into contact with the free end at a specified small distance from the axis of rotation of the clamp. A measured moment large enough to produce approximately a 30-deg bend is added to the balanced beam and the resulting Bend Angle of the wire observed. Bend Energy may also be calculated. Bend Angle observation is sometimes made 30 sec after load application where the wire continues to sag significantly after elastic oscillations cease. Angles other than 30 deg are sometimes used although this angle is usually most sensitive to small differences in temper.

See also *Kink Test* and *Repeated Bend Test.*

## Bendability

A measure of Ductility of metals obtained from a Bend Test and usually expressed in one of five ways: Bend Angle; Maximum Bend Angle; Minimum Bend Radius; Bend Elongation; or Bend Energy. Since Bend Test procedures are not widely standardized, a test result should be accompanied by complete details on specimen and procedure.

## Bending Deflection, Maximum

A measure of the extent to which a material can be bent without rupture. The maximum deflection of the specimen at the center of the span in the Flexure Test.

## Bending Strength

An alternate term for Flexural Strength employed particularly with cast iron. Not to be confused with Bendability.

## Breaking Strength

A measure of ability of a material to withstand stretch loading without rupture. A Tensile Strength for thin sheet and film materials. Ordinarily it is the maximum load (lb, kg or lb/in. width) observed in the Breaking Test. For plastic sheet and film it is determined by a Tension Test.

## Breaking Test

A method of measuring ability of a material to withstand stretch loading without rupture. A modified Tension Test for thin sheet and film materials. A rectangular specimen is gripped at both ends and stretched at a constant rate of extension until it ruptures. Maximum load is observed and Breaking Strength calculated. The test is used particularly for varnished vegetable (D295-52T) and glass fabric (D902-53T) cloth and tapes; untreated electrical insulating paper (D202-53T); pressure-sensitive adhesive tapes (D1000-53T); asbestos cloth (D577-52) and tape (D315-52); felt (D461-51); woven fabrics (D39-49); and rubber-coated fabrics (D721-52T). Asbestos tape is often tested after a 5-min heating period at 570 F. Tensile Strength is sometimes calculated for felt. Woven fabrics may be tested wet or dry and specimens may be "grab", "raveled-strip" or "cut strip". The grab-specimen is 4x6 in. The raveled-strip specimen is $1\frac{1}{4}$ or $1\frac{1}{2}$ in. wide with each side raveled so that net width is 1 in. The cut strip specimen is similar to the raveled-strip specimen except that it is cut to the 1-in. net width. The specimen for rubber-coated fabrics may be 4 in. ("grab") or 1 in. ("strip") wide. Elongation is usually determined for woven and rubber-covered fabrics.

## Brinell Hardness

A common measure of Indentation Hardness of a metal. An index of resistance to surface penetration by a hard ball under load in a Brinell Hardness tester (E10-50T). It is calculated by dividing applied load by calculated surface area enclosed by the rim of the impression remaining after load is released:

$$BHN = \frac{2P}{\pi D (D - \sqrt{D^2 - d^2})}$$

where BHN = Brinell Hardness No., kg/mm²
P = load, kg
D = ball dia, mm
d = measured impression dia, mm

The greater the Brinell Hardness, the greater the Indentation Hardness of the metal. Tables giving Brinell Hardness for any measured impression diameter are available for standard loads and types of indentors. Brinell Hardness is generally influenced by magnitude of indenting load, ball diameter and ball material, and these factors should be specified. Ordinarily, loads are 3000, 1500 or 500 kg, and ball diameter is 10 mm. A carbide ball can be used for Brinell Hardness up to 630, the Hultgren ball is limited to 500 and a hardened steel ball to 450. The 3000-kg load is usually limited to the 160-600 hardness range, 1500 kg to the 80-300 range, and 500 kg to the 26-100 range. Loads of 250, 125 or 100 kg are sometimes used for the softer metals. Where a ball indentor smaller than 10 mm is used, load is altered accordingly. Load is applied for at least 15 sec on ferrous metals, at least 30 sec on many nonferrous metals, and at least 2 min on magnesium. A definite, not a minimum, duration of load application should be specified for the softer metals. In comparison with the Rockwell and Vickers tests, the Brinell test is particularly useful where deep penetration is desired to avoid surface effects or where a large impression is desired to avoid errors due to inhomogeneity of the material. It is not adapted to materials as thin or as hard as can be tested by other methods, and results cannot be read directly as on the Rockwell tester.

## Brittleness Temperature

An indication of the extent to which service temperature can be lowered without causing plastics or elastomers to exhibit brittle behavior (due to crystallization, etc.) under load. The temperature at which 50% of the specimens fail when a specified number are subjected to equivalent impacts at equal increments of temperature over a range that includes both the temperature at which all specimens fail and the temperature at which no specimens fail (D746-52T). Each rectangular strip is supported as a cantilever beam and struck once perpendicularly near its free end. At least 10 specimens are tested at each temperature and the percentage of specimens that fail at each temperature is determined. Ordinarily the test begins at the temperature at which 50% failure is expected and temperature is changed in constant increments in both directions until percentages of 0 and 100 are obtained. Either short-time or long-time temperature effects may be evaluated, depending on conditioning procedure. Brittleness Temperature is calculated as follows:

$$T_b = T_h + \Delta T \left( \frac{S}{100} - \frac{1}{2} \right)$$

where $T_b$ = Brittleness Temperature, C
$T_h$ = highest temperature at which all specimens fail, C
$\Delta T$ = temperature increment, deg C
S = sum of percentage breaks at each temperature, %

Brittleness Temperature does not necessarily indicate the lowest temperature at which a material can be used.

## Bulk Modulus of Elasticity

The ratio of stress to change in volume of a material subjected to axial loading. It is calculated as follows:

$$K = \frac{E\,r}{3(1-2r)}$$

where K = Bulk Modulus of Elasticity, psi
E = Modulus of Elasticity, psi
r = Poisson's Ratio.

## Bursting Strength

A measure of ability of a material to withstand hydrostatic pressure without rupture. It is obtained from a Pressure Test for rigid materials or a Bursting Test for flexible

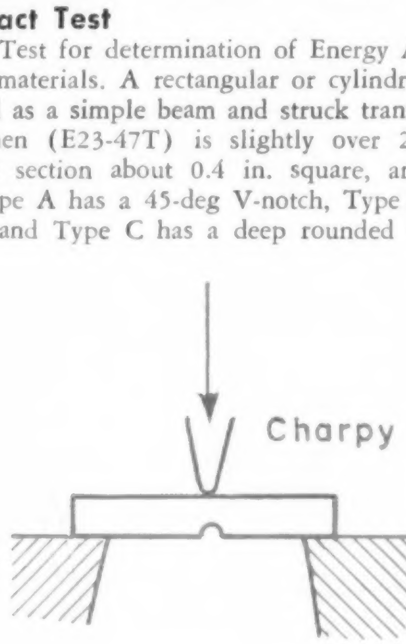
materials. For metals it is generally the maximum Hoop stress sustained by a material prior to rupture. For glass or rigid plastics it may be the maximum Radial Stress sustained by a material prior to rupture, in which case Bursting Strength is valid only for material of the same dimensions. For flexible sheet and film materials, Bursting Strength is calculated by dividing maximum net pressure observed in the Bursting Test by cross section area of the exposed diaphragm portion of the specimen.

**Bursting Test**

A method of determining ability of nonmetallic sheet and film to withstand pressure without rupture. A Pressure Test for determining Bursting Strength of flexible materials. Usually the specimen is clamped as a diaphragm and expanded by a tool or another diaphragm under gradually increasing mechanical or fluid pressure, respectively, until rupture. For electrical insulating paper (D202-53T), vulcanized fiber, felt and rubber-coated fabrics (D751-52T) a 1.2-in.-dia diaphragm is used and maximum pressure prior to rupture observed. For the heavier materials a "tare" pressure for the diaphragm may be measured and subtracted from gross pressure. For rubber coated fabrics, pressure may also be applied by means of a 1-in.-dia steel ball.

**Charpy Impact Test**

An Impact Test for determination of Energy Absorption in fracture of materials. A rectangular or cylindrical specimen is supported as a simple beam and struck transversely. The steel specimen (E23-47T) is slightly over 2⅛ in. long, has a cross section about 0.4 in. square, and is usually notched. Type A has a 45-deg V-notch, Type B has a keyhole notch and Type C has a deep rounded slot. Notches




for nonferrous metals or more ductile metals are often sharper and deeper than for steel. The die casting specimen is 3 in. long and has a slightly trapezoidal cross section measuring about ¼ in. It is unnotched and is struck on its smallest face. The cast iron specimen is an 8-in. cylinder of 1⅛ in. dia (A327-50T). The specimen for plastics, vulcanized fiber, glass-bonded mica and other electrical insulating materials (D256-47T) is 5 in. long, ½ in. wide and ½ in. or less thick, with a 22½-deg V-notch across the narrower side. The ceramic specimen is an unnotched cylinder 6 in. long and ½ to 1⅛ in. dia. All Charpy specimens are struck at their center of gravity, on the face opposite any notch, and at the center of any notch. Both metals and plastics (D758-48) are tested at subnormal and elevated temperatures.

**Cold Flow**

A measure of the extent to which hard rubber deforms under prolonged loading. The reduction in thickness under load in a specified time at a specified temperature (D530-50T). A solid or plied-up ½-in. cube is subjected to a perpendicular compressive load of 1000 lb at room temperature and resulting thickness measured immediately. The specimen is then heated to 120 F, kept under load for 24 hr, and thickness is measured again. Cold Flow (%) is calculated by dividing difference in thickness by original thickness under load and multiplying by 100.

**Compressibility**

The ability of a material to be compressed. The extent to which a gasket material is compressed by a specified load in the short-time Compressibility and Recovery Test. Compressibility (%) is calculated by dividing difference between original thickness under preload and thickness under major load by original thickness under preload and multiplying by 100. It is usually reported in conjunction with Recovery and does not indicate behavior of a material under prolonged load.

**Compressibility and Recovery Test**

A method of measuring behavior of gasket materials when subjected to and released from short-time compressive loading at room temperature. A compressive preload is applied to a flat specimen for 15 sec at which time specimen thickness under preload is measured. The major load is then applied slowly and full load maintained 60 sec, at which time thickness under major load is measured. The major load is then removed, and 60 sec later recovered thickness under preload is measured. From these measurements Compressibility and Recovery are calculated. Specimen size, penetrator size and loads depend on the nature of the material tested (D1147-53T). The specimen has a square or circular cross section of at least 1 to 4 sq in. and single or plied-up thickness of 1/16 to ⅛ in. The penetrator is a steel cylinder of ¼ to 1⅛ in. dia. Major loads range from 50 lb for most materials to 100 lb for cork and 250 lb for compressed asbestos. This test differs from the Plastometer Test in that the latter measures behavior of a material subjected to prolonged loading at an elevated temperature.

**Compression Fatigue**

A measure of ability of vulcanized rubber to withstand deterioration when subjected to dynamic compression strains. A specimen is subjected to rapidly oscillating compressive stresses, and such quantities as extent and rate of temperature rise of the specimen, impressed loads, dimensional changes and time needed for failure are observed. Results are reported in different ways depending on which of three different tests (D623-52T) is used. Method A is covered under *Goodrich Flexometer,* Method B under *Firestone Flexometer* and Method C under *St. Joe Flexometer.*

**Compression Set**

A measure of the extent to which vulcanized rubber is permanently deformed by a prolonged compressive load. Not to be confused with Low-Temperature Compression Set where permanent deformation is not involved. Two test methods (D395-53T) are used and their results are not comparable. Method A determines Compression Set as the percentage permanent decrease in thickness caused by a prolonged constant compressive load. Method B determines Compression Set as the percentage of a prolonged constant compressive deformat'on that is permantly retained. Specimen for both methods is a solid or plied-up cylindrical disk about ½ in. thick and 1⅛ in. dia.

In Method A, original thickness is measured, a 400-lb axial load applied, and the specimen clamped to maintain the resulting deflection. The assembly is heated at a temperature selected on the basis of expected service conditions, two standard treatments being 22 hr at 158 F and 70 hr at 212 F, both in dry air. The specimen is then removed from oven and clamp and allowed to cool 30 min, at which time final thickness is measured. Method A Compression Set (%) is the Compressive Strain calculated by dividing change in thickness by original thickness and multiplying by 100.

In Method B, a spacer of such thickness as to provide a predetermined percentage deflection is placed between the compression plates. Amount of deflection is selected on the basis of Durometer Hardness; up to 44, deflection is 40%;

45 to 64 — 30%; 65 to 84 — 25%; 84 and over — 20%. Otherwise, procedure is similar to Method A, but Method B Compression Set (%) is calculated by dividing overall change in thickness by difference between original thickness and spacer thickness and multiplying by 100. For latex foam rubber (D1055-53T) and sponge and expanded cellular rubber (D1056-53T) Method B, with deflection of 50% and temperature of 158 F, is standard.

Choice of test method depends on whether expected service conditions involve constant application of a known load (Method A) or maintenance of a known deflection (Method B). Compression Set is meaningless where dynamic or repeated loading is involved.

## Compression Test

A method of determining behavior of a material subjected to a uniaxial compressive load. A specimen is compressed axially at controlled speed until it fails. Frequent or continuous measurements of load and deformation are made, Compressive Stress and Strain calculated, and a Stress-Strain Diagram constructed. From the Stress-Strain Diagram can be determined Elastic Limit, Modulus of Elasticity, Proportional Limit, Yield Point, Yield Strength and, for some materials, Compressive Strength. The last two properties may also be determined without a Stress Strain Diagram.

For Yield Point, the load at which load temporarily ceases to increase with continued deformation is noted. For Compressive Strength, the load at fracture or at some other predetermined degree of failure is noted. Specimens for metals (E9-52T) are usually solid cylindrical or rectangular sheet types. For electrical porcelain (D116-44) the standard specimen is a solid cylinder 1⅛ in. dia and 1⅛ in. high and loads, not stresses, at both initial and ultimate failure are usually reported along with a description of the behavior of the material under load. For rigid plastics (D695-52T) and glass-bonded mica the most common specimen is a 1-in. high cylinder or square prism of ½-in. dia or width. The prism is standard for molded electrical insulating materials (D48-52T). The sheet specimen for plastics and other electrical insulating materials (D229-49) consists of 1-in. square plied up to at least 1-in. height. A 1-in. ring section is used for both ordinary and laminated (D348-52) tube, and the small ordinary and laminated (D349-52) rod specimen ranges from ½ to 2 in. in height, depending on rod diameter. Both metals and plastics (D759-48) are tested at subnormal and elevated temperatures.

## Compression-Deflection Test

A nondestructive method of determining the relationship between compressive load and deflection under load for vulcanized rubber. Two test methods (D575-46) are used. The first determines the stress needed to produce a specified deflection. The second determines the deflection producd by a specified load. Either a standard specimen or a part may be tested, although only the results from similar specimens are comparable. The standard specimen is a cylindrical disk about ½ in. thick and 1⅛ in. dia.

In the first method, an axial compressive load is applied slowly until a specified percentage deflection is produced, and the load is then released at the same rate. This conditioning cycle is repeated once. Next a small load is applied and the deflection gage zeroed. Full load is applied as before, the load needed to produce the specified deflection noted, and the corresponding Compressive Stress calculated. Where the stresses needed for several different deflections are desired, they may be obtained from a Stress-Strain Diagram constructed on the basis of frequent measurements of load and deflection during the loading cycle. Standard deflection for sponge and expanded cellular rubber (D1056-53T) is 25%.

In the second method, a specified minor load is applied and the deflection gage zeroed. A specified major Compressive Stress is then applied axially, deflection produced by it alone noted after 3 sec, and corresponding Compressive Strain (%) calculated. Chief advantage of this method is its rapidity.

## Compressive Deformation

A measure of the extent to which a material deforms under compressive loading prior to rupture. The total strain (%) of a specimen immediately prior to rupture in the Compression Test as indicated by direct measurement or by a Stress-Strain Diagram.

## Compressive Modulus of Elasticity

Also called Modulus of Elasticity in Compression. The tangent or secant Modulus of Elasticity of a material in the Compression Test. The relationship between Compressive Stress and corresponding Compressive Strain.

## Compressive Strain

The strain corresponding to a specified distress in a Compression, Compression-Deflection, Compression Set or similar test.

## Compressive Strength

A measure of ability of a material to withstand compressive loading without failure. The maximum Compressive Stress developed by a material in the Compression Test. Compressive Strength is a relatively independent property only in materials that fail in compression with a shattering fracture. For other materials, Compressive Strength can only refer to the stress at which a specified degree of distortion, arbitrarily selected as indicative of failure, is observed.

## Compressive Stress

The stress corresponding to a specified strain in a Compression, Compression-Deflection, Compression Set or similar test. It is calculated by dividing applied compressive load by orginal area of the cross section perpendicular to the loading direction.

## Compressive Yield Strength

The Yield Strength of a material in the Compression Test.

## Crack Growth Resistance

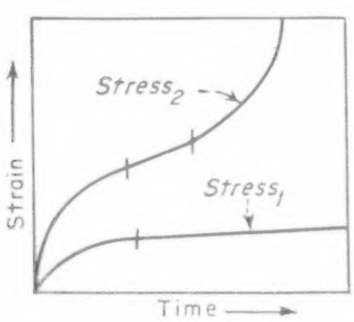
A measure of resistance of rubber to growth of a crack under repeated bend flexing. Two tests are used. In the De Mattia Flexing Machine Test, Crack Growth Resistance may be expressed as number of cycles needed to reach a specified crack length, average rate (in./kc) of crack growth over the entire test period, or rate of cracking (in./kc) during a specified portion of the test. In the Ross Flexing Machine Test, Crack Growth Resistance is usually expressed as number of cycles needed for each 100% increase in crack length up to 500%. Crack Growth Resistance does not necessarily indicate ability of a material subjected to bend flexing to resist initial formation of a crack (Cracking Resistance).

## Cracking Resistance

A measure of ability of vulcanized rubber to withstand repeated stretching or bend flexing without cracking. Two tests are used. In the DuPont Flexing Machine Test, the rubber is subjected to three tensile flexes for each compressive flex. Cracking Resistance is expressed as number of flexures at which all of 21 specimens tested together exhibit some sign of failure. In the De Mattia Flexing Machine Test, the rubber may be subjected to either stretching or bend flexing, as specified. When each of several specimens tested together exhibits some sign of failure, number of cycles is noted and each specimen is assigned a number representing degree of cracking obtained by com-

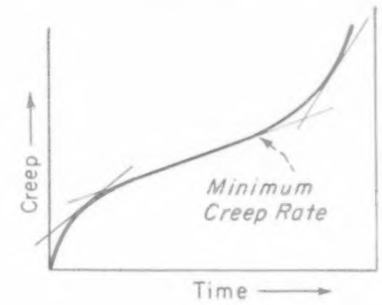
parison with a graded series of 11 specimens numbered from 0 (no cracking) to 10 (cracked through). Cracking Resistance is expressed as average grade number accompanied by number of test cycles.

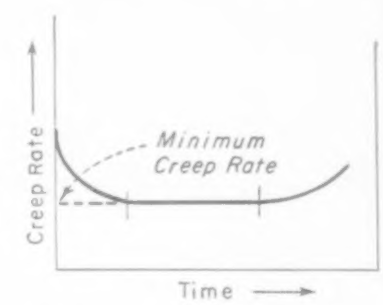
### Creep
The strain of a material subjected to prolonged constant stress or load for a specified time in a Creep Test or a Stress Rupture Test. Creep behavior is often presented in the form of graphs. The simplest graph is a plot of strain vs. log of time. For metals, strain may be either total measured strain, or where total strain is of the same order of magnitude as elastic strain, net strain due to plastic deformation only. This net strain is determined by obtaining the strain corresponding to the specified constant stress on the Stress-Strain Diagram for the specified temperature and subtracting it from total measured strain. For plastics, strain may be either total measured strain, in which case the graph also indicates strain of the corresponding control specimen, or net strain due to Creep only. This net strain




is obtained by subtracting corresponding control specimen strain from total measured strain. A log-log plot is often preferred for plastics. For vulcanized rubber, total measured deformation (mm) is plotted against log of time (sec), and the magnitude of elastic deformation is indicated by drawing a tangent to the curve at 60 sec. From these graphs, Creep of metals or plastics is the total or net strain at the specified time, and Creep of vulcanized rubber is the difference between total deformation and 60 sec tangent deformation at the specified time. Creep of vulcanized rubber may also refer to the Yerzley Mechanical Oscillograph Test where it is the vertical distance (in.) or reduction of thickness (%) represented by the difference between the beginning and end of the damped sinusoidal curve after a specified time. Creep of hard rubber is measured as Cold Flow. A Creep design chart may be constructed by plotting stress vs log of time for each of a series of limiting deformations. From such a chart, Creep Strength for various limiting deformations may be determined. Creep Rate and Creepocity may also be determined from Creep data.

### Creep Rate
The rate (in./in./hr or %/hr) at which Creep occurs. It is usually obtained from a plot of total or net strain vs time. Creep Rate at a specified time is equal to the slope of the tangent to the curve at that time. Average Creep Rate over a period of time is equal to the difference between total or net strain at the beginning and at the end of that period divided by the amount of time encompassed by the period. Where Creep data are available for several different temperatures and constant stresses, a log-log graph of Creep Rate at a specified time vs stress is sometimes plotted. Such a graph indicates the effects of both stress and temperature on Creep Rate. For any material that creeps more slowly during an intermediate period than at the beginning or end of a test, Minimum Creep Rate can be determined by plotting Creep Rate vs time. For metals Minimum Creep Rate corresponds to the slope of the approximately linear curve representing second-stage Creep. From Creep Rate may be predicted the increase in strain that will occur over a specified period of time. Alone, it provides no information on either total or net accumulated Creep at any time. However, if the amount of strain corresponding to the intersection of the Creep Rate tangent




and the 0-time axis is known, total Creep at any time may be calculated by adding this strain to the product of Creep Rate and total specified time.

### Creep Rate, Minimum
See *Creep Rate.*

### Creep Recovery
A measure of the rate of decrease in strain that occurs at a specified constant temperature when load is removed from a material after prolonged application in a Creep Test. Load is removed from the specimen at a specified time or total strain, and total strain remaining after instantaneous recovery is measured immediately. Subsequently, frequent measurements of total strain and elapsed time are made. At any specified time following load removal, Creep Recovery is equal to the difference between total strain immediately following load removal and total strain at the specified time. Creep Recovery may be presented as a plot of Creep Recovery vs elapsed time following load removal.

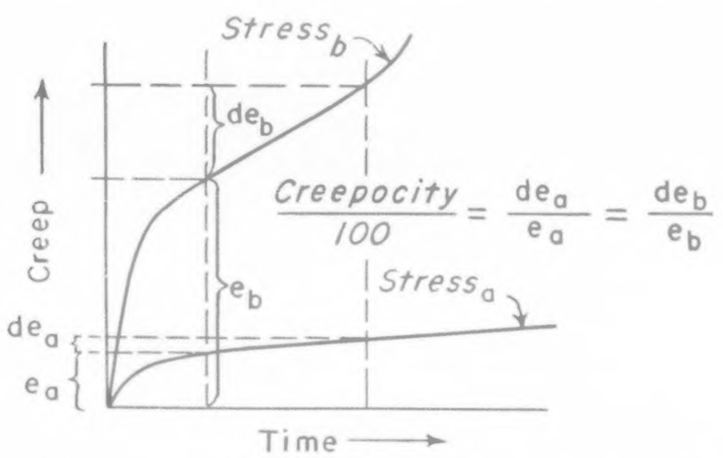
### Creep Strength
A measure of ability of a material to withstand prolonged static loading. The maximum Tensile or Compressive Stress that can be sustained by a material for a specified time at a specified temperature without rupturing, without deforming beyond a specified limit, or without exceeding a specified limiting Creep Rate. Ultimate Creep Strength is determined from the stress-rupture curve obtained in the Stress Rupture Test. Creep Strength for a specified limiting deformation is determined from a Creep design chart obtained in the Creep Test. Creep Strength for a specified limiting Creep Rate is determined from a plot of Creep Rate at the specified time vs stress.

### Creep Test
A term for several different methods of determining Creep and Stress Relaxation behavior of a material subjected to prolonged static tensile or compressive loading at room or elevated temperatures. In determination of Creep, the material is subjected to prolonged constant stress or load and constant temperature, and frequent measurements of time and elongation are made. In determination of Stress Relaxation, the material is subjected to prolonged constant strain and constant temperature, and frequent measurements of time and stress or load made. For metals (E22-41) and plastics (D674-51T), specimens are somewhat similar to those used in the Tension or Compression Tests. Where total strain of metals is of the same order of magnitude as elastic strain, magnitude of elastic strain is usually determined at each test temperature by applying load stepwise and constructing a Stress-Strain Diagram or, if first-stage Creep is too rapid for accurate measurements, by measuring elastic strain occurring immediately upon release of load at the end of the test. Conditioning of plastics is particularly important in a Creep Test because changes in moisture content, plasticizer content and state of polymerization not only affect Creep and Stress Relaxation behavior but also produce dimensional changes that may be sufficient to obscure Creep or Stress Relaxation. For vulcanized rubber (D1206-52T), the Creep specimen is a thin rectangular

strip suspended vertically and subjected to an axial Tensile Stress of 2 kg/cm². Creep of hard rubber is measured by a special test for Cold Flow. Stresses employed in the Creep Test for metals are of such magnitude that rupture does not often occur within a practical test period. For plastics, stresses employed in the Creep Test are such that rupture often occurs within 1000 hr. For simplicity, the rupture behavior of both metals and plastics is considered under Stress Rupture Test. Metal or plastic specimens that do not fracture within the test period may be used to determine Creep Recovery.

## Creepocity

The relationship between Creep and time at a specified temperature. The percent increase in strain from one specified time to another as determined from the Creep Test. If Creepocity is determined on the basis of a single stress, the stress should be specified. Since Creepocity is




often almost independent of stress, values at different stresses are sometimes averaged and the result given as Creepocity. Where average Creepocity is valid, a plot of Creepocity vs temperature often provides a useful basis for comparison of Creep behavior of various materials over a specified period of time.

## Crush Test

A method of determining the extent to which metal tubing can be compressed axially without failure. A "pass or no pass" test in which a ring section about 2½ in. high is compressed a specified amount and visual examination made to ascertain whether failure has occurred. Practically, the test is limited to tubing of such dimensions that the ratio of outside diameter to thickness is neither large nor small. Performance of a material in this test is sometimes referred to as its Crushability.

## Crushability

The relative ability of a material to be compressed without failure. The term may refer to Compressive Strength, or, more often, the ability of tubing to withstand a specified Compressive Strain as measured in the Crush Test. In the latter case, Crushability is considered an indication of Ductility in mild steel and some nonferrous tubing.

## Crushing Load

A measure of the maximum compressive load a material can withstand without failure. The force (lb) or stress needed to produce a predetermined degree of failure in the Compression Test where a true Compressive Strength cannot be determined for the material.

## Cup Blank Diameter, Maximum

The diameter of the largest of a series of flat circular blanks of a metal that can be drawn to a cup of specified diameter without failure. A comparative index of the formability of metal sheet. Since the Cup Drawing Test is not standardized, the likelihood of obtaining comparable results in two different shops is small. Even with identical equipment and procedures, the difference between two materials can be ascertained only where sheet thicknesses are equal.

## Cup Drawing Test

A term for several different methods used to determine formability of sheet metal. See *Cup Height* and *Cup Blank Diameter, Maximum.*

## Cup Height (or Depth)

A measure of Ductility of sheet metal. A sheet specimen may be clamped between two ring-shaped dies and a hemispherical punch forced against one side of the sheet; or successive cups may be formed across a long strip with plunger depth increased a specified amount for each cup, as for rolled zinc (B69-39). Cup Height (or Depth) is usually the height or depth of the dome at the first appearance of fracture, but it may also be the height of the dome at which a sudden drop in punch pressure occurs. Cup Height is usually expressed in 0.01 mm (Erichsen Test) or 0.001 in. (Olsen Test). A variety of cupping tests are used and results cannot properly be compared except where such factors as clamping pressure, smoothness of dies and punch, lubrication, punching speed and end point of the test are identical and carefully controlled. Compensations must also be made for width and thickness of the specimen. Cup Height tends to increase as specimen width decreases because the edges "draw in". Cup Height also increases approximately linearly as sheet thickness increases; the correction may be ascertained from standard formulas and graphs. Cup Height can be measured rapidly and requires no specimen preparation. It is a good indicator of wide variations in Ductility and a good measure of the likelihood of surface roughening in forming operations. Scatter is too wide for reliable detection of small differences between materials.

## De Mattia Flexing Machine Test

A method of determining Cracking Reisistance or Crack Growth Resistance of rubber.

For Cracking Resistance (D430-51T), the rubber may be flexed in tension or in bending. The tension specimen is the dumbbell type (C) used in the Tension Test. The bend flex specimen is a 6x1x¼-in. rectangular strip with a transverse rounded notch on one side. The specimen is gripped at both ends in the De Mattia Flexing Machine and flexed at 300 cpm. The bend flex specimen is held so that the groove is across the convex surface. Several specimens are tested simultaneously and number of cycles prior to the appearance of the first minute sign of cracking is noted. The test is then continued until all specimens exhibit some sign of failure at which time total number of cycles is noted.

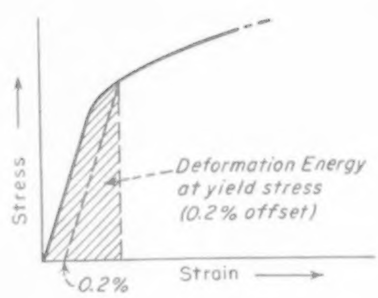
Specimen and procedure for Crack Growth Resistance (D813-52T) are similar to those for the bend flex test above except that an 0.080-in. crack is pierced in the bottom of the specimen groove. Length of the developed crack is measured frequently. Usually the test continues until the crack is 0.5 in. and sometimes until rupture.

## Decrease in Thickness Under Pressure

A measure of the extent to which pasted mica sheet deforms under load and heat (D352-52). A 1-in. stack of 3x2-in. pieces are clamped together between parallel plates, a pressure of 100 psi applied, and thickness of the stack measured. Bolts are tightened to maintain the resulting deflection and the stack is heated to 320 F and held 5 min at that temperature. Heat is then removed and a pressure of 2000 psi applied and held until the stack returns to room temperature, at which time stack thickness is again measured. Decrease in Thickness (%) is calculated by dividing difference in thickness under the two loads by thickness under the preload and multiplying by 100.

## Deformation Energy

The energy (in.-lb/in.³) needed to deform a material a specified amount. The area under the curve on a Stress-Strain Diagram up to the specified strain. For rubber, Deformation Energy is generally the energy needed to produce a specified static compressive deformation of rubber




in the Yerzley Mechanical Oscillograph Test and is calculated as follows:

$$e_c = 40\,A$$
$$e_s = 10\,A$$

where $e_c$ = Deformation Energy in compression, in.-lb/in.$^3$
$e_s$ = Deformation Energy in shear, in.-lb/in.$^3$
A = Area under Load-Deflection curve down to specified deflection, in.-lb.

The numerical factors compensate for differences in volume of specimens and in scales used in compression and shear tests.

## Deformation Under Load

A measure of the extent to which plastics and other molded electrical insulating materials deform under prolonged compressive loading. Two methods (D621-51) are used: Method A for rigid plastics, and Method B for nonrigid plastics.

In Method A, a ½-in. solid or plied-up cube is subjected to a specified axial compressive load, usually 250, 500 or 1000 lb, and a specified temperature usually 73.4, 122 or 158 F. Specimen height is measured after 10 sec of loading and again after 24 hr, at which time load is released and height is measured again immediately. Method A Deformation Under Load (%) is calculated by dividing change in height occurring under load by "original height" and multiplying by 100. For this purpose, "original height" is calculated by adding change under load to the height measured after release of the load. Deformation Under Load (Method A) indicates the extent to which a rigid plastic will tend to yield and loosen in a mechanically fastened assembly. It can also be used as an index for comparison of long-time stiffness at various temperatures.

In Method B, a disk about 1⅛ in. dia and ½ in. thick is subjected to an axial compressive load of 100 lb at a specified temperature, usually 73.4, 122 or 158 F. Disk thickness is measured immediately upon loading and again after 3 hr, at which time load is released, but temperature is maintained for 1 hr. Heat is then removed and the specimen exposed to room temperature for 30 min, at which time recovered thickness is measured. Method B Deformation Under Load (%) is calculated by dividing change in thickness occurring under load by original thickness and multiplying by 100. Recovery may also be found.

## Diamond Pyramid Hardness

A common measure of Indentation Hardness of metals. Also called Vickers Hardness. An index of resistance to surface penetration by a square-based 136-deg pyramidal diamond indentor under a specified load. It is calculated by dividing applied load by calculated projected area of the impression:

$$DPH = \frac{1.8544\,L}{d^2},$$

where DPH = Diamond Pyramid Hardness, kg/mm$^2$
L = load, kg
d = length of diagonal of impression, mm.

A table (E92-52T) gives solutions for this formula where L is 1 kg. DPH Hardness for other loads may be found by assuming a 1-kg load and multiplying corresponding DPH Hardness by actual load used.

## Drop Ball Impact Test

An Impact Test for determining Energy Absorption of a material in fracture. A metal ball of known weight is dropped upon the part or specimen from regularly increasing heights. The height at which the material exhibits the first sign of failure and the height at which it ruptures are noted. The test is used especially for hard metals, ceramics, metal-ceramics and plastics. See also *Repeated Blow Impact Value.*

## Du Pont Flexing Machine Test

A method of determining Cracking Resistance of rubber (D430-51T). The specimen is 7½ in. long, 4 in. wide and about 3/16 in. thick with a raised corrugated section and seven transverse 120-deg V-notches. The specimens are mounted on a fabric base to prevent stretching and 21 are linked together and run as a belt around the four pulleys of the Du Pont Flexing Machine. The rubber is subjected to three tensile flexes and one compressive flex during each complete revolution. The test continues until all specimens show some sign of failure and total number of cycles is noted.

## Ductility

The extent to which a material, particularly a metal, can sustain plastic deformation without rupture. Bendability, Crushability, Elongation Reduction of Area and Wrapping Diameter, results of Cup Draw, Flattening, Kink, Repeated Bend and Twisting Tests are considered some indication of Ductility.

## Durometer Hardness

A measure of Indentation Hardness of rubber (D676-49T). A flat annular presser foot is brought into contact with the rubber part or specimen. Durometer Hardness indicates the extent to which a spring-loaded hardened steel indentor operating through the presser foot protrudes beyond it either immediately or a specified amount of time after contact between foot and rubber surface has been made. Since the scale is based on readings of 100 when both foot and indentor are pressed firmly on flat pure plate glass and 0 when the indentor extends 0.100 in. beyond the foot, a higher Durometer Hardness indicates a greater Indentation Hardness.

## Dynamic Modulus, Effective

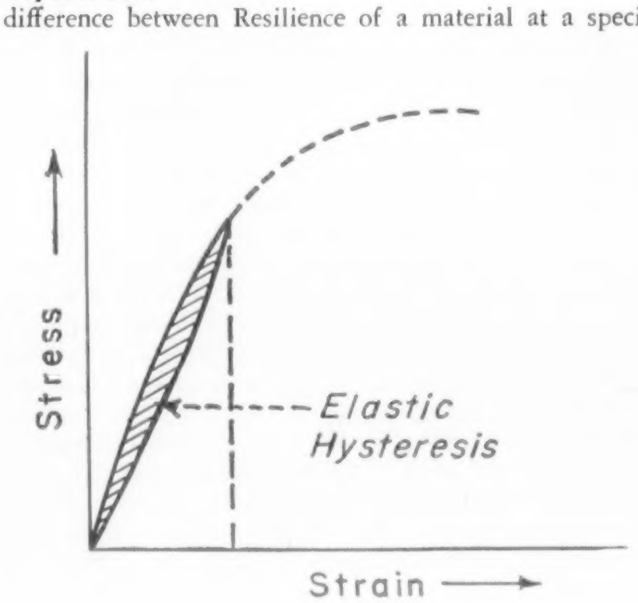
An indication of vibration absorption characteristics of rubber. A measure of dynamic stiffness of rubber deformed beyond the straight-line portion of the Load-Deflection Diagram in the Yerzley Mechanical Oscillograph Test. It is calculated as follows:

$$K_c = 210\,If^2$$
$$K_s = 105\,If^2$$

where $K_c$ = Effective Dynamic Modulus in compression, psi
$K_s$ = Effective Dynamic Modulus in shear, psi
I = moment of inertia of beam and weights, slug ft$^2$
f = Frequency, cps

## Elastic Hysteresis

The difference between Resilience of a material at a speci-



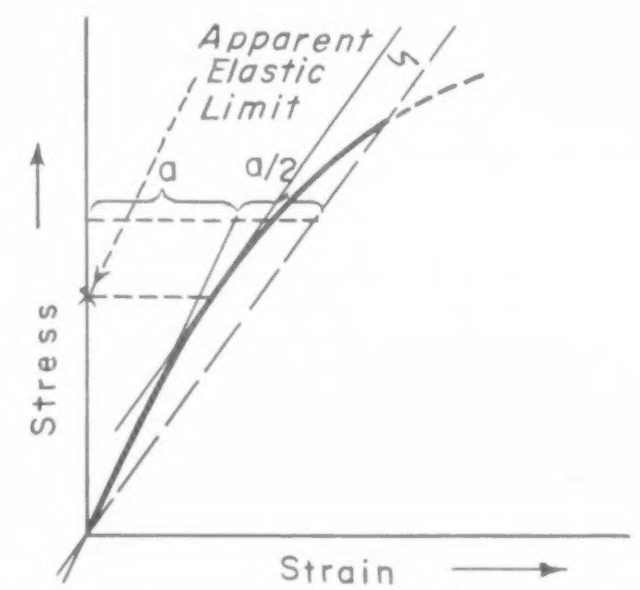
fied stress and Deformation Energy recovered from the material unloaded from the same stress, the loading and unloading occurring at a constant and specified rate.

**Elastic Limit**

The greatest stress a material is capable of developing without a Permanent Set remaining upon complete release of the stress. Practically, it is the highest stress for which no Permanent Set can be measured with the instruments used. Ordinarily, Elastic Limit and Proportional Limit of metals are considered to be approximately equal, and Elastic Limit is determined as the highest stress on the straight-line portion of the Stress-Strain Diagram. Yield Point and Yield Strength are widely used approximations of Elastic Limit. An Apparent Elastic Limit is often determined for materials that do not exhibit a significant Proportional Limit.

**Elastic Limit, Apparent**

An arbitrary approximation of Elastic Limit for a material that does not exhibit a significant Proportional Limit. It is obtained from a Stress-Strain Diagram and is equal to the




stress at which the rate of strain is 50% greater than at zero stress. It is determined as the stress at the point of tangency between the curve and a line having a slope with respect to the stress axis 50% greater than the slope of the curve at the origin.

**Elongation**

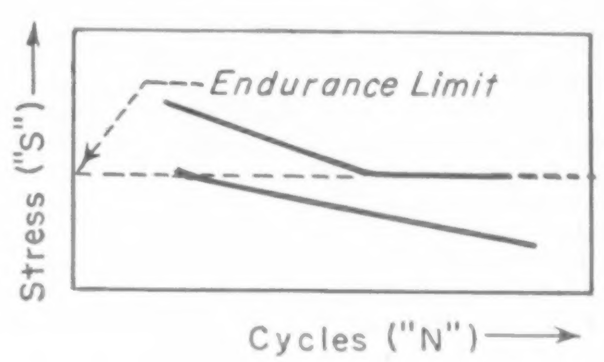
A term that is both general and specific. Generally, the extension of a material in the Tension Test at any specified point (e.g. Yield Point Elongation). Specifically, the extension of a material at rupture (see also *Residual Elongation*) in the Tension Test. Generally, Elongation (%) is calculated by dividing total increase in gage length by original gage length and multiplying by 100. At rupture, Elongation (%) is usually calculated by dividing total permanent increase in gage length by original gage length and multiplying by 100. Total permanent strain can be measured by fitting the broken specimen together after rupture or by subtracting strain at the Elastic Limit from total strain indicated by a Stress-Strain Diagram. For any material with high Modulus of Elasticity and an important degree of Elongtion, the error introduced by using total strain obtained from extensometer or Stress-Strain Diagram instead of total permanent strain is insignificant. Elongation of metals in short gage lengths is quite sensitive to the effects of localized extension occurring at the center of the "necked down" portion of the specimen, and gage length must therefore be specified. Elongation cannot be used to predict other mechanical properties but is considered an indicator of Ductility in metals. As such it is used to predict both formability and the extent to which a metal can deform in service without rupture. However, Elongation may have little relation to the highly localized extension occurring in many forming operations, and Elongation specified for structural materials often has little relation to the much smaller extension actually permitted by service conditions. Elongation cannot be used to predict behavior of materials subjected to sudden or repeated loading.

**Elongation, Residual**

A measure of Ductility of plastics. The Elongation of a plastic specimen measured 1 min after rupture in the Tension Test.

**Endurance Limit**

A measure of load-carrying ability of a material subjected to infinitely-repeated loading. A special limiting value of Fatigue Strength for some materials. The maximum alternating stress amplitude that can be sustained by a material subjected to a specified mean stress for an infinite number of cycles without failure. It is obtained from the S-N Diagram in the Fatigue Test and is equal to the constant




stress corresponding to that portion (if any) of the curve which is parallel or asymptotic to the "N" axis. Endurance Limit has no real meaning for a material that does not exhibit the type of S-N curve described above. Actually the term is often used as an alternate for Fatigue Strength for such materials, but number of cycles actually tested should be specified.

**Energy Absorption**

A term that is both general and specific Generally, it refers to the energy absorbed by any material subjected to loading. Specifically it is a measure of Toughness or Impact Strength of a material; the energy needed to fracture a specimen in an Impact Test. It is the difference in kinetic energy of the striker before and after impact, expressed as total energy (ft-lb or in-lb) for metals and ceramics, and energy per inch of notch for plastics and electrical insulating materials. A higher Energy Absorption indicates a greater Toughness. For notched specimens, Energy Absorption is an indication of the effect of internal multiaxial stress distribution on fracture behavior of the material. It is merely a qualitative index and cannot be used directly in design. Notch behavior of most metals can be deduced from results of the Tension Test, but notch behavior of ferritic steels is not predictable. Transition Temperature, derived from a series of Energy Absorption measurements, is commonly specified for such materials. Energy Absorption is quite sensitive to variations in materials and in test conditions, especially temperature, striking speed and energy, and specimen size and shape. Only results for identical specimens and notches may safely be compared. If a metal has reasonably high Energy Absorption at a specified temperature, it is assumed that it will exhibit ductile fracture at all higher temperatures. Other properties representing measurements of Energy Absorption in its general sense include Bend Energy, Deformation Energy, Elastic Hysteresis, Impact Resilience, Kinetic Energy in Elastomeric Spring Resilience, Scleroscope Hardness.

**Equivalent Yield Stress**

A convenient index of relative strength of thermosta

metals at various elevated temperatures (B191-50). A rectangular specimen is used for flat strip, and a helix formed by wrapping 10 or more turns on a diameter at least 20 times material thickness is used for helical coils. The specimen is supported as a simple beam and subjected to two equal, measured and gradually increasing loads at equal distances from the supports, and the load at which the material exhibits a specified Permanent Set is observed. Equivalent Yield Stress is calculated as follows:

$$S = \frac{6\,Pl}{b\,h^2}$$

where S = Equivalent Yield Stress, psi
P = each load at yielding, lb.
l = each span, in.
b = material width, in.
h = material thickness, in.

It must be indicated whether the high-expansion side of the bimetal is tested in tension or compression.

### Erichsen Cup Test

See *Cup Height*.

### Expansion Test

Also called Flaring Test. A tapered pin is forced into the end of a tube a distance sufficient to produce a specified increase in tube diameter, and the tube is examined to determine whether failure has occurred. The pin usually has a 60-deg included angle, and expansion usually ranges from 15 to 40%. Primarily a control and acceptance test for nonferrous metal tubing.

### Fatigue Life

An indication of the useful life of a material subjected to repeated loading. The number of cycles of loading of specified magnitude and direction that can be withstood by a material without failure. It is obtained from the S-N Diagram in the Fatigue Test. The S-N curve is such that "N" or "life" values change rapidly with small changes in "S" or stress values. Therefore, Fatigue Life is usually determined on the basis of a stress somewhat higher than estimated actual service stress.

### Fatigue Notch Factor

Also called Strength Reduction Ratio. A measure of the actual effect of a notch or other stress concentrator on Fatigue Strength of a material. The ratio of measured Fatigue Strength of a material free of known stress concentrators to that a material with known stress concentrators, assuming specimens are otherwise comparable and test conditions identical. The empirical Fatigue Notch Factor is usually lower than the theoretical Stress Concentration Factor because of stress relief that occurs in conjunction with local plastic deformation. For a given material, a higher Fatigue Notch Factor indicates the likelihood of a lower Fatigue Strength or Endurance Limit.

### Fatigue Ratio

The ratio of Fatigue Strength or Endurance Limit to Tensile Strength. For many materials it is constant enough so that Fatigue Strength can be estimated from Tensile Strength, provided that stress concentration conditions in test and service are comparable.

### Fatigue Strength

A measure of load-carrying ability of a material subjected to loading that is repeated a definite number of times. The maximum alternating stress amplitude that can be sustained by a material, subjected to a specified mean stress, for a specified number of cycles without failure. It is obtained from the S-N Diagram in the Fatigue Test. Endurance Limit is a special limiting value of Fatigue Strength. The S-N curve is such that "N" or "life" values change rapidly with small changes in "S" or stress values, and therefore Fatigue Strength is usually determined on the basis of a life many times estimated actual service life. Fatigue Strength of ferrous metals determined under conditions of completely reversed axial stress is sometimes converted to Fatigue Strength under conditions of unreversed or partially reversed stress by the following empirical formula:

$$S_m = S_e \left(\frac{3}{2 - r}\right)$$

where $S_m$ = Fatigue Strength, psi
$S_e$ = Fatigue Strength for completely reversed stress, psi
r = ratio of minimum to maximum stress, the sign being negative for completely or partially reversed stress

The expression in parenthesis may vary with different materials and loading conditions (e.g. $\frac{2.25}{1.25 - r}$ for aluminum and $\frac{2}{1 - r}$ for shear loading).

### Fatigue Test

A method of determining maximum life or maximum load for a material subjected to repeated loading. A specified constant or "mean" stress (which may be zero) and a superimposed specified cyclic stress (known as "alternating stress amplitude") are applied to the material and the number of cycles needed to produce failure observed. Results are usually presented in the form of an S-N Diagram on which values of alternating stress amplitude ("S") are plotted against log of the corresponding numbers of cycles required for failure ("N"), each curve representing a specified mean stress. Fatigue Life, Fatigue Strength and Endurance Limit are determined from the S-N Diagram.

The loads may be applied axially, in torsion or in flexure and the cyclic load may be unidirectional, completely reversed or partially reversed. Depending on the combination of mean stress and alternating stress amplitude, therefore, the maximum net stress in one direction may be more than, equal to or less than the maximum net stress in the opposite direction, or all net stresses may be in one direction. Loads corresponding to specified stesses may be calculated as in corresponding static tests (Tension, Compression, Torsion and Flexure Tests). Where mean stress is not zero, considerable Creep may occur for some plastics at ordinary temperatures and for most materials at elevated temperatures.

Most Fatigue Tests are made in flexure on either rotating beam or vibratory type machines. A rotating beam machine suspends a constant load from the specimen and rotates it rapidly as a fully-supported or cantilever beam, each rotation completing a stress cycle. A vibratory machine may flex a specimen by magnetic excitation or by utilizing the centrifugal force of a rotating wheel transmitted to the specimen fully supported as a beam, but usually the specimen is supported as a cantilever beam and vibrated by an eccentric wheel. Both notched and unnotched specimens are used, depending on whether information is desired on behavior of a material under optimum conditions or on the effect of various stress concentrators on behavior of a material. Metal specimens have not been widely standardized. An unnotched specimen for a rotating beam test is generally cylindrical with a gradual reduced section at the center. In a notched rotating beam specimen the gradual reduced section is replaced by a circumferential narrow reduced section having a diameter 50 to 85% of overall diameter. A vibratory specimen is generally rectangular with a gradual reduced section in either width or thickness amounting to a center reduction of about 40%. A notch or hole may be added in the reduced section to act as a stress raiser. The unnotched vibratory cantilever specimen for plastics (D671-51T) is a ¾-in.-square beam with a span of 3½ in. and a gradual reduced cross section measuring 0.3 in. square at the center. For sheet the specimen is rectangular with only the width reduced. Notched plastic specimens are flat rectangles with either a transverse

shallow V-notch on one side or, for thin sheet, a 0.120-in. hole at the center.

The common criterion of fatigue failure is complete separation of the specimen into two pieces, but some plastics containing fibrous fillers do not separate rapidly upon cracking. For such materials reduction of stiffness by 12½% is the criterion of failure provided no large temperature rises ensue. Practically, this point is determined by measuring increase in load needed to increase deflection of the cantilever beam from one specified value to another before the test, and repeating the same determination frequently after cracking starts until the required load falls to ⅞ of original load.

### File Hardness

A statement as to whether a file does or does not bite into a material. A simply-obtained comparative property generally ascertained only for metal parts.

### Firestone Flexometer Test

A method of determining Compression Fatigue characteristics of rubber. A frustrum of a rectangular pyramid with 2⅛x1⅛ base, 2x1 top and 1½-in. altitude is subjected to a specified axial compressive load and resulting vertical deflection measured. The specimen is then subjected to an additional off-center oscillating compressive load until a specified additional deflection is achieved. Frequent measurements of specimen temperature are made. Results are given as number of load cycles needed to produce the specified additional deflection, accompanied by temperature changes involved.

### Flange Test

A flange is formed on a short section of tubing and examined for evidence of failure. An indication of flange-formability of nonferrous and mild steel tubing.

### Flaring Test

See *Expansion Test.*

### Flattening Test

A measure of Ductility of metal pipe. A short section of pipe, generally 3-4 in. long, is crushed diametrically between parallel plates to a specified extent and examined for failure (A370-53T). A "pass or no pass" acceptance test generally not feasible where the ratio of pipe diameter to thickness is less than 10.

### Flexing Fatigue Resistance

A measure of resistance of latex foam rubber to deterioration as a result of repeated compression. A specimen of known height is subjected to compressive oscillations at 60 cpm and amplitude of 25 or 50%. The larger amplitude is used for materials with an Indentation value less than 1.34 psi. Flexing Fatigue Resistance is indicated by number of cycles needed to produce failure of the cellular structure as determined by visual examination and comparison with unflexed specimens (D1055-53T). Results are sometimes accompanied by Compression Set determined at 250,000 cycles.

### Flexural Modulus of Elasticity

The Modulus of Elasticity of a material in the Flexure Test. It may be calculated from a Load-Deflection Diagram as follows:

$$E_F = \frac{L^3}{4bh^3}\left(\frac{P}{Y}\right) \text{ (for rectangular specimen)}$$

$$E_F = \frac{0.425\,L^3}{d^4}\left(\frac{P}{Y}\right) \text{ (for round specimen)}$$

where $E_F$ = Flexural Modulus of Elasticity, psi
$\frac{P}{Y}$ = slope of initial straightline portion of curve on Load-Deflection Diagram, lb/in.
L = span, in.
b = specimen width, in.
h = specimen thickness, in.
d = specimen diameter, in.

Flexural Modulus of Elasticity for plastics (D747-50) and other molded electrical insulating materials (D48-52T) is sometimes determined by another method based on angle of deflection. A rectangular specimen is supported in a vise as a cantilever beam. The vise is part of a relatively simple lever apparatus which is so constructed that angular deflection and a quantity proportional to corresponding bending moment can be read from "deflection" and "load" scales respectively. The beam is bent a few degrees at a time, deflection and load being read at each interval, usually until total angular deflection is about 30 deg. Load scale reading (in.) is plotted against deflection scale reading (deg). If the straight-line portion of the resulting curve does not pass through the origin it is translated parallel to itself until it does. Flexural Modulus of Elasticity is calculated by substituting load scale reading and angular deflection corresponding to any point on the translated straight line in the following equation:

$$E_F = \frac{L\,M\,P}{0.436\,b\,h^3\,\theta}$$

where P = load scale reading, in.
$\theta$ = deflection scale reading, deg
M = weight on pendulum, lb
L = span, in.

A cantilever specimen is also used in a rapid method of establishing a secant modulus, particularly to determine variation of modulus with temperature for thermostat metals (B223-51T). The rectangular strip specimen is so preformed that the free end has a slight upward curvature. A vertical measured load sufficient to depress the beam as much below the horizontal as it was above is applied to the free end and resulting total deflection observed. Flexural Modulus of Elasticity is calculated as follows:

$$E_F = \frac{4\,P\,L}{Y\,b\,h^3}$$

A Low Temperature Modulus is sometimes determined for rubber.

### Flexural Strength

A measure of ability of a material to withstand rupture when subjected to bend loading. The Ultimate Strength of a material in the Flexure Test. The maximum Flexural Stress that can be sustained by a material without rupture. It is calculated by substituting maximum load in the Flexure Test for P in the formula for Flexural Stress. Flexural Strength of a somewhat ductile metal is often considerably higher than Tensile Strength. Although no constant relationship has been established, a higher Flexural Strength in a material having little Ductility usually indicates a higher Tensile Strength.

### Flexural Stress

The maximum nominal tensile or compressive stress developed by a material subjected to a specified bending load in the Flexure Test. It is calculated as follows:

$$S = \frac{1.5\,PL}{bh^2} \text{ (for rectangular specimen)}$$

$$S = \frac{2.546\,PL}{d^3} \text{ (for round specimen)}$$

where S = Flexural Stress, psi
P = bending load, lb.
L = span, in.
b = specimen width, in.
h = specimen thickness, in.
d = specimen diameter, in.

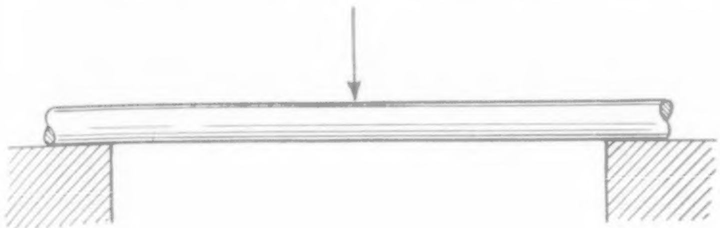
### Flexural Yield Strength

The Yield Strength of a material in the Flexure Test.

### Flexure Test

Also called Transverse Bend Test. A method of determining behavior of a material subjected to bend loading. A

cylindrical bar or rectangular strip is supported usually as a simple beam and subjected to a measured and increasing bending load at the center of the span. Frequent or continuous measurements of both bending load and deflection at the center of the span are made until rupture occurs and



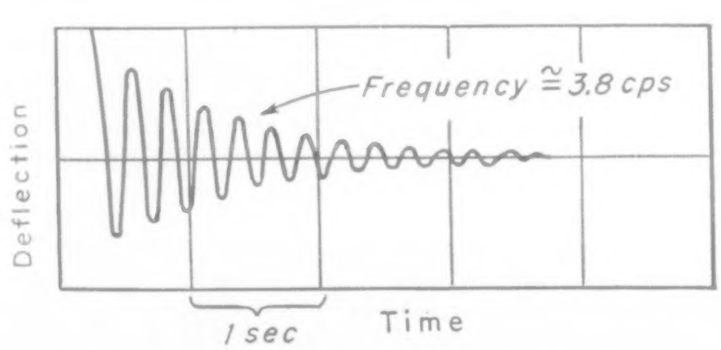
a Load-Deflection Diagram is constructed. Properties determined from the Flexure Test include Flexural Modulus of Elasticity, Flexural Strength, Flexural Yield Strength and Maximum Bending Deflection. Reliable data on hard and brittle materials such as cast iron, tool steels, sintered carbides and metal-ceramics are more readily obtained from the Flexure Test than the Tension Test, and slight variations in properties are more evident than in an Impact Test. The cylindrical specimen for cast iron (A48-48) ranges from ⅞ to 2 in. dia and 12 to 24 in. in span. Specimens for hard steels are usually smaller. For molded rigid plastics, glass-bonded mica and other electrical insulating materials (D790-49T) the rectangular specimen may be ½ in. wide, ¼ in. thick and 4 in. in span. Sheet specimens have a span equal to at least 16 times thickness, and the span of laminated round rod (D349-52) is eight times diameter. For some sheet electrical insulating materials less than 1/16 in. thick, the span is 4 in. for edgewise tests and ½ in. for flatwise tests (D229-49).

### Fluting Diameter

The smallest diameter about which sheet metal can be bent to form a smooth curve rather than a series of planes with a fluted appearance.

### Frequency

An indication of vibration absorption characteristics of rubber obtained from the Yerzley Mechanical Oscillograph




Test. Frequency (cps) is calculated by dividing a convenient number of complete cycles in the oscillograph curve by horizontal distance (in.) which is equivalent to the corresponding time (sec) required.

### Gehman Torsional Test

A special Torsion Test used to determine stiffening behavior of rubber at low temperatures (D1053-52T). A thin rectangular strip about 1½ in. long and ⅛ in. wide is twisted axially in a controlled temperature chamber. The torsion wire has a constant such that total angular deformation of the specimen is between 120 and 170 deg when the torsion head is turned 180 deg. Temperature is increased from below the freezing point to room temperature. At each temperature total angle of twist of the specimen produced by a 180-deg turn of the torsion head is observed and the results are plotted as a graph of twist angle vs. temperature. Modulus of Rigidity and Relative Modulus may be determined for any temperature. Test results are often given as the temperatures at which Relative Modulus has certain specified values (2, 5, 10 and 100 are common). The test may also be used to evaluate effects of long-term cold hardening at a specified temperature, in which case log of Relative Modulus is plotted against time.

### Goodrich Flexometer Test

A method of determining Compression Fatigue characteristics of rubber having Durometer Hardness less than 85. A cylinder or truncated cone 1 in. high and about ¾ in. dia is subjected to two axial compressive loads: one is either a specified load or the load needed to produce a specified deflection, and the other is a superimposed high frequency (1800 cpm) cyclic load of specified amplitude. Frequent measurements of temperature at the base of the specimen are made, and sometimes continuous measurements of specimen height are made. The test may end at a predetermined time, at the time no further temperature rise occurs, or upon blowout failure. Except where failure occurs, specimen height is measured 1 hr after load is released and Permanent Set may be calculated. Test results may be expressed in several different ways: temperature rise in a specified time; Permanent Set in a specified time; duration of heat buildup; maximum temperature rise; and time to failure. For any time at which specimen height is known, degree of stiffening or softening may be estimated by comparing change in height at that point with calculated Permanent Set.

### Hardness

The resistance of a material to plastic deformation. Different aspects of Hardness may be determined by indenting, scratching or bouncing a projectile from the material. File Hardness is a simple test for scratch Hardness, and Scleroscope Hardness is a common rebound test. Most common tests, however, are of the Indentation Hardness type.

### Heat Distortion Temperature

A measure of the practical upper temperature limit for an ordinarily rigid plastic subjected to external load (D648-45T). A 5-in. solid or plied-up rectangular strip ½ in. thick and ⅛ to ½ in. wide is supported as a simple beam with 4-in. span and subjected to a bending load sufficient to produce a Flexural Stress of either 264 psi or 66 psi, as specified. After load has been applied 5 min, the deflection gage is zeroed and the specimen heated at 5C/min until a deflection of 0.010 in. is observed. Heat Distortion Temperature is the temperature at which 0.010 in. deflection is observed for the specified Flexural Stress.

### Heat Distortion Test

A method of determining effect of elevated temperatures and time on strength of glass-bonded mica (D1039-50T). A rectangular specimen similar to that used in determination of Heat Distortion Temperature of plastics is supported as a simple beam and subjected to a center load sufficient to produce a specified Flexural Stress. Deflection of the center of the beam is measured after both 1 and 24 hr at a specified elevated temperature. Results are usually given as the deflections at both times for each test temperature selected.

### Hoop Stress

The circumferential stress in a material of cylindrical form subjected to internal or external pressure in the Pressure Test. For thin-wall cylinders, it is calculated as follows:

$$S = \frac{PD}{2t}$$

where S = Hoop Stress, psi
P = applied pressure, psi
D = specimen o.d., in.
t = wall thickness, in.

This relationship, known as "Barlow's formula", does not hold for thick-wall specimens where stress varies appreciably in the cross section and more complex analysis is required.

## Impact Resilience

A measure of dynamic energy absorption of rubber. The extent to which the Goodyear-Healey pendulum rebounds from a specimen after dropping a specified height (D1054-53T). A rectangular block 1x1x2 in. is subjected to 10 preliminary pendulum impacts from a 15-deg height to establish equilibrium in the specimen. Three test impacts from 15 deg are then made and highest rebound angle is observed. Impact Resilience is expressed as percentage of rebound. Since energy absorbed is proportional to vertical displacement of the pendulum, Impact Resilience (%) may be read directly from prepared tables or calculated as follows:

$$R = \frac{1 - \cos \text{angle of rebound}}{0.0003408}$$

Since depth of penetration of the pendulum in the rubber is considered to be a related property, it is usually reported in conjunction with Impact Resilience. Penetration is measured by means of a micrometer screw, electrical contacts and headphones. Initial and final deflections are measured and the difference between them adjusted to compensate for the difference in length of the pendulum at point of penetration and at point of measurement. Penetration is reported in 0.001 in. The Goodyear-Healey pendulum is often modified for various purposes and results are not always directly comparable. Impact Resilience of metals is measured by Scleroscope Hardness.

## Impact Strength (or Resistance)

An alternate term for Energy Absorption as determined by an Impact Test. A measure of Toughness. Use of this term is questionable, particularly in connection with single-blow Impact Tests, since such tests do not measure impact behavior so much as they measure fracture behavior.

## Impact Test

A destructive test in which the material is subjected one or more impacts of specified magnitude and Energy Absorption or a proportionate value is determined. The Drop Ball Impact Test and the Repeated Blow Impact Test utilize a series of impacts that increase in severity until failure occurs. The most common Impact Tests utilize a single impact sufficient to produce failure. There are three common types of single-blow impact tests, depending on direction of load application and manner in which the cylindrical or rectangular specimen is held. In the Charpy Impact Test, the specimen is supported as a simple beam and load is transverse. In the Izod Impact Test, the specimen is supported as a cantilever beam and load is transverse. In the Tension Impact Test, the specimen is supported at one end and the load is axial and tensile. In each case the blow is delivered by a pendulum striker. The test may be conducted at various specified levels of velocity (linear velocity of striker at impact) and energy (energy of striker at impact). The Impact Test is highly controversial and its results must be carefully interpreted for proper application. Impact Resilience and Scleroscope Hardness are determined by nondestructive Impact Tests.

## Indentation

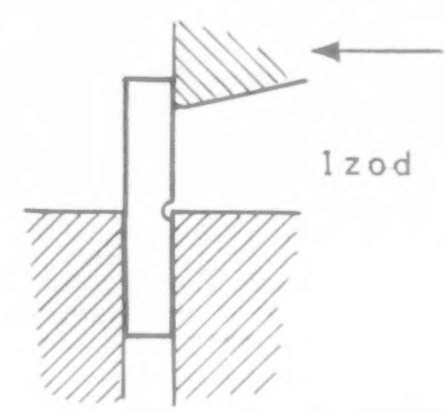
A measure of Indentation Hardness of latex foam rubber (D1055-53T). The stress needed to produce 25% indentation. The flat specimen is of full thickness and at least 1 ft square. It rests on a perforated plate which allows air to escape during compression. A preload of 1 lb is applied to the indentor, which is a flat circular foot of 50-sq-in. area, and specimen height is measured. The specimen is then compressed an amount equal to 25% of measured height and the corresponding load is observed. Indentation (psi) is calculated by dividing observed load by 50.

## Indentation Hardness

The ability of a material to resist penetration by an indentor forced into its surface by a perpendicular load. For most nonmetallics, Indentation Hardness has somewhat limited use, but for many metals it is a useful index of strength and sometimes an indication of certain fabricating properties. Definite relationships between Indentation Hardness and the Tensile and Compressive Strengths of steel and cast iron have been established, but no such definite relationships have been established for other mechanical properties or for nonferrous metals. A higher Indentation Hardness for a metal is often considered to be an indication of greater wear resistance, lower machinability and lower formability, but usable relationships can be established only where criteria are agreed upon and all other conditions are closely controlled. Indentation Hardness is measured by: Alpha Rockwell Hardness, ASTM Hardness, Brinell Hardness, Diamond Pyramid Hardness, Durometer Hardness, Knoop Hardness, Monotron Hardness, Pusey and Jones Indentation, Rockwell Hardness, Rockwell Penetration, Rockwell Recovery and Rockwell Superficial Hardness.

## Izod Impact Test

An Impact Test for determination of Energy Absorption or Toughness in fracture of materials. A rectangular or cylindrical specimen is supported as a cantilever beam and struck transversely. A common rectangular steel specimen (E23-47T) is about 3 in. long with a cross section about 0.4 in. square and a transverse 45-deg V-notch. Two cylindrical specimens—Type Y with a circumferential notch, and Type Z with a machined flat striking surface—are also used. The gray cast iron specimen (A327-50T) is a 3-in. unnotched cylindrical bar about 0.8 in. dia. The Izod Test




is generally not suitable for austenitic or malleable iron. The rectangular specimen for plastics, vulcanized fiber, glass-bonded mica and other electrical insulating materials (D256-47T) is 2½ in. long, ½ in. wide and up to ½ in. thick, with a 22½-deg V-notch across the narrower side. All notched Izod specimens are supported with notch center line in the plane of the supporting edges and struck on the notch side at a specified point between the notch and the unsupported end. Many modifications of the Izod Test have been made to eliminate the error introduced by the energy imparted to the free broken part of the specimen. The error is particularly significant for low-strength nonmetallic materials. Both metals and plastics (D758-48) are tested at subnormal and elevated temperatures.

## Kinetic Energy in Elastomeric Spring

A measure of vibration absorption characteristics of rubber. The maximum kinetic energy (in.-lb/in.$^3$) absorbed by rubber in the Yerzley Mechanical Oscillograph Test calculated as follows:

$$E_c = \frac{4\,n\,h_1}{V}$$

$$E_s = \frac{2\,n\,h_1}{V}$$

where $E_c$ = maximum Kinetic Energy in compression, in.-lb/in.$^3$

$E_s$ = maximum Kinetic Energy in shear, in.-lb/in.$^3$

n = number of unbalanced weights

$h_1$ = vertical distance of downstroke of first cycle of

damped sinusoidal curve, in.
V = volume of specimen, in.$^3$

### Kink Test

A method of determining Ductility of wire. A short section of wire is looped, then drawn in tension by hand to kink it. Occurence or non-occurrence of failure is an indication of relative Ductility. Another indication is the extent to which a successful kink may be opened up without failure.

### Knoop Hardness

A measure of Indentation Hardness of a material. An index of resistance to surface penetration by a standard pyramidal diamond indentor under specified load. Knoop Hardness is equal to applied load (kg) divided by projected area of impression (sq mm). Projected area is calculated by squaring the length of the longer diagonal of the impression and multiplying it by a constant characteristic of the indentor. The standard indentor has an included longitudinal angle of 172°30′ and an included transverse angle of 130°0′. Ratio of lengths of diagonals of the impression is 7.11:1. Loads range from 25 g to 50 kg, and the test is particularly useful where a shallow impression is desired.

### Load-Deflection Diagram

A graph on which is plotted load vs corresponding deflection of a material. In the Flexure Test, a Load-Deflection Diagram is usually necessary for determination of Flexural Modulus of Elasticity and Flexural Yield Strength. It is often useful in determination of Flexural Strength and Maximum Bending Deflection. A stress cannot be read directly from the Load-Deflection Diagram but must be calculated as the Flexural Stress corresponding to the appropriate load. A Load-Deflection Diagram may also be constructed from the stepwise load-deformation graph obtained in the Yerzley Mechanical Oscillograph Test. It consists of a smooth hysteresis loop drawn through the points of intersection of the horizontal lines with the vertical lines from which they originate. Since each step in the original graph represents an increase of 20 psi in compression or 10 psi in shear, the stress corresponding to any load on the derived curve can be readily estimated.

### Low-Temperature Compression Set

A measure of ability of vulcanized rubber loaded at room temperature and then subjected to a prolonged low temperature to recover from such deformation while still at the low temperature. The percentage of a prolonged constant compressive deformation that is retained when load is released at the low temperature. The test (D1229-52T) is similar to Method B described under Compression Set, except that test temperatures usually range from 20 to −65 F, time under load is usually 22 or 94 hr, and final specimen thickness is measured 10 sec, as well as 30 min, after load release. Compression Set is calculated as in Method B for both 10 sec and 30 min. Low-Temperature Compression Set, unlike Compression Set determined by Methods A or B, is not permanent, since the material returns to its original dimensions when heated to room temperature or slightly higher. The test simulates to some extent conditions encountered in seal and gasket applications for aircraft and submarines.

### Low-Temperature Deflection

A measure of the effect of low temperatures on Compressibility of latex foam rubber (D1055-53T) and sponge and expanded cellular rubber (D1056-53T). The load needed to produce 25% deflection in a disk ½ in. thick and about 1⅛ in. dia is determined by the Compression-Deflection Test at room temperature. The specimen is then conditioned for 5 hr at −40 F, at which time the same compressive load is applied and resulting deflection measured immediately. Percentage deflection is calculated by dividing observed deflection by original specimen thickness and multiplying by 100. Low Temperature Deflection (%) is calculated by subtracting observed percentage deflection from 25 and multiplying the result by four.

### Low-Temperature Modulus Test

A method of determining stiffness of rubber at low temperatures. A rectangular strip about 1 in. wide and ¼ in. thick is supported as a simple beam with a span of 2 in. Two test methods (D797-46) are used, depending on whether time effects are negligible (second order transition) or not (crystallization).

In the first method, a load sufficient to cause a small deflection is applied to the center of the span and allowed to remain 10 sec. The load is then removed and after 10 sec resulting net deflection of the center of the beam is measured. The same load is reapplied and allowed to remain 15 sec at which time deflection under load is measured. The modulus is calculated by the first equation under Flexural Modulus of Elasticity except that P is applied load and Y is difference in deflection readings. The calculation may be simplified by means of a nomograph. The modulus is determined at 70, 32, −40 and −70 F, sometimes at lower temperatures, and often at other convenient intervening temperatures. Results are usually presented in the form of a plot of Flexural Modulus of Elasticity vs temperature. Where a specific application is involved one or more limiting modulus values corresponding to predetermined temperatures may be reported if crystallization and other time effects are known to be absent.

In the second method, Flexural Modulus of Elasticity is determined at −4 F (32 F for neoprene) as above. The specimen is then held 72 hr at test temperature after which the modulus is again determined. A considerably larger modulus after 72 hr indicates the presence of crystallization or other time effects.

### Modulus

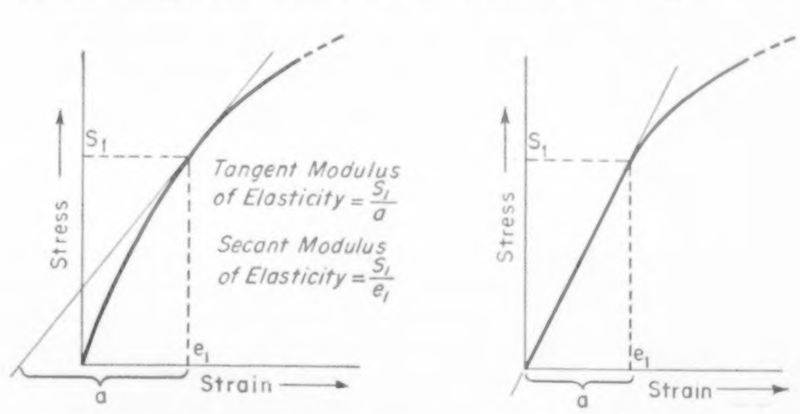
The Tensile Stress of rubber corresponding to a specified Elongation. Also, sometimes, an abbreviation for Modulus of Elasticity or Modulus of Rigidity.

### Modulus, Static

The tangent Modulus of Elasticity of rubber obtained from the Yerzley Mechanical Oscillograph Test.

### Modulus of Elasticity

A measure of stiffness of a material. Not to be confused with Modulus of rubber. A term applied to two different relationships between stress and strain below the Elastic Limit. Tangent Modulus of Elasticity is the slope of a Stress-Strain Diagram at a specified stress. Secant Modulus of Elasticity is the ratio of stress to strain at a specified stress or strain. It is also called the Stress-Strain Ratio. For a material exhibiting a true Proportional Limit of any significant magnitude, both moduli are equal to the slope of the straight-line portion of the Stress-Strain Diagram




and are therefore equal to each other. For a material without a definite Proportional Limit, the two moduli may differ significantly. For many materials, the Proportional Limit is nominal in that the stress-strain curve is only approximately the straight line predicted by Hooke's Law. For such materials the two moduli are different but usually

the difference is of no practical significance. Depending on the type of loading represented by the Stress-Strain Diagram, Modulus of Elasticity may be known as Compressive Modulus of Elasticity (or Modulus of Elasticity in Compression), Flexural Modulus of Elasticity (or Modulus of Elasticity in Flexure), Shear Modulus of Elasticity (or Modulus of Elasticity in Shear), Tensile Modulus of Elasticity (or Modulus of Elasticity in Tension), or Torsional Modulus of Elasticity (or Modulus of Elasticity in Torsion). Shear Modulus of Elasticity is almost invariably equivalent to Torsional Modulus of Elasticity and they are more commonly known as Modulus of Rigidity. The term Modulus of Elasticity alone generally refers to Tensile Modulus of Elasticity. Moduli of Elasticity in Tension, Compression or Flexure are usually approximately equal for a given material and may be calculated from Modulus of Rigidity as follows:

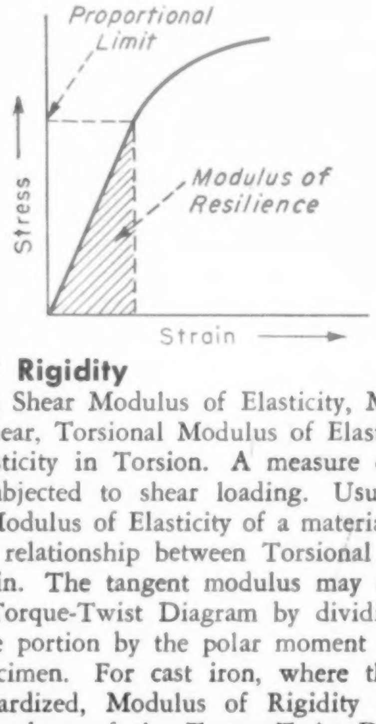
$$E = 2G\,(1 + r)$$

where $E$ = Modulus of Elasticity, psi
$G$ = Modulus of Rigidity, psi
$r$ = Poisson's Ratio

Below the Elastic Limit, Modulus of Elasticity may be used to predict the stress corresponding to a specified strain or vice versa. A higher Modulus of Elasticity indicates greater stiffness. See also *Dynamic Modulus*.

## Modulus of Resilience

The Resilience of a material subjected to a stress corresponding to its Proportional Limit.




## Modulus of Rigidity

Also called Shear Modulus of Elasticity, Modulus of Elasticity in Shear, Torsional Modulus of Elasticity and Modulus of Elasticity in Torsion. A measure of stiffness of a material subjected to shear loading. Usually the tangent or secant Modulus of Elasticity of a material in the Torsion Test. The relationship between Torsional Stress and Torsional Strain. The tangent modulus may also be obtained from the Torque-Twist Diagram by dividing slope of the straight-line portion by the polar moment of inertia (in.$^4$) of the specimen. For cast iron, where the specimen has been standardized, Modulus of Rigidity is calculated by multiplying slope of the Torque-Twist Diagram by 32.2. In the Gehman Torsional Test, Modulus of Rigidity is calculated as follows:

$$G = \frac{0.795\,K\,(180 - \theta)}{b\,h^3\,\mu\,\theta}$$

where $G$ = Modulus of Rigidity, psi
$\theta$ = total angular deflection, deg
$K$ = torsional constant of wire, g-cm/deg twist
$b$ = specimen width, in.
$h$ = specimen thickness, in.
$u$ = factor based on b/h

Modulus of Rigidity may also be calculated from Modulus of Elasticity in Tension, Compression or Flexure:

$$G = \frac{E}{2\,(1 + r)}$$

where $E$ = Modulus of Elasticity, psi
$r$ = Poisson's Ratio

An Apparent Modulus of Rigidity is sometimes determined for plastics.

## Modulus of Rigidity, Apparent

An approximation of Modulus of Rigidity determined for plastics by a special limited Torsion Test (D1043-51). A fixed small torque of less than 1 in.-lb is applied to a rectangular strip $2\frac{1}{2}$ in. long and $\frac{1}{4}$ in. wide and total angular deflection observed. Apparent Modulus of Rigidity may be calculated by substituting (917 TL) for 0.795K $(180 - \theta)$ in the numerator of the formula for Modulus of Rigidity, where T is applied torque (in.-lb) and L is specimen twist length (in.). Ordinarily the test is conducted at several different temperatures for the purpose of indicating effect of temperature on stiffness.

## Modulus of Rupture

The Ultimate Strength of a material as determined by the Flexure or Torsion Test. Modulus of Rupture in Flexure is an alternate term for Flexural Strength. Modulus of Rupture in Torsion is an alternate term for Torsional Strength.

## Monotron Hardness

A measure of Indentation Hardness of a metal. The load (kg) needed to press a specified ball indentor a specified depth into the surface. Most common indentor is a 0.75-mm diamond. Use of alternate indentors is indicated by scale designations as follows: 1-mm diamond (M-2); 1/16-in. tungsten carbide (M-3); 2.5-mm tungsten carbide (M-4). Standard depth of penetration is 0.045 mm but, for hard materials, depth of indentation may be limited to 0.015 mm and resulting load multiplied by three.

## Olsen Cup Test

See *Cup Height*.

## Permanent Set

The extent to which a material is permanently deformed by a specified load. Permanent Set (%) is calculated by dividing difference in a dimension in the direction of loading before and after the load cycle by original dimension and multiplying by 100.

## Plasticity Number

A measure of Compressibility of rubber at elevated temperatures. An index of the height of a standard specimen under a 5-kg load after a specified loading period at a specified temperature in the Plastometer Test. Compression times most commonly used are 3 or 10 min. Plasticity Number is calculated by multiplying measured height (mm) by 100. A lower Plasticity Number indicates greater compressibility. Plasticity Number is usually reported in conjunction with Recovery and is required for calculation of Method A Recovery.

## Plastometer Test

A method of determining ability of rubber to be compressed at an elevated temperature and to recover at room temperature (D926-47T). The standard specimen is a solid or plied-up cylinder $\frac{1}{2}$ in. high and about 9/16 in. dia. Test temperatures vary from room to 212 F, but 158 and 212 F are common. The specimen is preheated 15 min before load is applied. Both Plasticity Number and Recovery are determined. This test differs from the Compressibility and Recovery Test in that the latter measures behavior of a material subjected to short-time loading at room temperature.

## Poisson's Ratio

The ratio of lateral strain to corresponding axial strain for a material subjected to axial loading. It may be obtained from suitable strain measurements made during a Tension or Compression Test. Poisson's Ratio for an isotropic material at a stress below the Proportional Limit may also be calculated as follows:

$$r = \frac{E}{2G} - 1$$

where r = Poisson's Ratio
E = Modulus of Elasticity in Tension or Compression, psi
G = Modulus of Elasticity in Shear, psi

### Pressure Test

A method of determining behavior of a material in hollow cylindrical form subjected to internal or external hydrostatic pressure. A Bursting Test for rigid materials. Two methods are used for internal tests. In one method, used for rigid plastic tubing (D11-80-51T), close-fitting cylindrical plugs of known diameter are fitted in the ends of the 2-6-in. long tube which contains a high-viscosity fluid. The plugs are forced slowly toward each other and applied load at rupture is observed. Bursting Strength is calculated on the basis of Radial Stress. In another method, used for metals and glass (C147-50), the closed tube or cylinder is subjected to measured and gradually increasing internal fluid pressure and maximum applied pressure prior to rupture is observed. Bursting Strength is calculated on the basis of Hoop Stress for metals and Radial Stress for glass. Sometimes a metal cylinder is immersed in water and volume of water displaced measured to determine Permanent Set of the material for a specified internal pressure. An external test, primarily for metals, is sometimes conducted either by immersing a closed-end specimen in the fluid or by sealing a pressure chamber around the circumference of an open-end specimen.

### Proportional Limit

The greatest stress which a material is capable of developing without a deviation from the law of proportionality of stress to strain (Hooke's Law). Theoretically, it is the highest stress at which the "curve" on the Stress-Strain

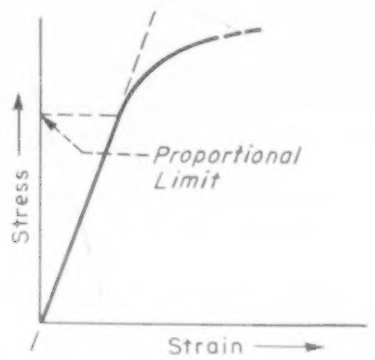



Diagram is a straight line. Practically, it is the highest stress on the curve for which no "offset" (see Yield Strength) from the tangent to the lower part of the curve can be measured with the instruments used. Proportional Limit and Elastic Limit of many metals are considered to be approximately equal.

### Pusey and Jones Indentation

A measure of Indentation Hardness of rubber. The depth of penetration (in 0.01 mm) of a specified ball indentor under 1-kg load obtained with the Pusey and Jones Plastometer (D531-49). The specimen is a 1¼x3-in. rectangular block ½ in. thick. The indentor is brought into contact with the specimen and the deflection gage zeroed. A 1-kg load is applied and deflection observed after 1 min. Standard indentor is ⅛ in. dia, but a ¼-in. indentor is necessary for some soft materials, in which case deflection is observed after 15 sec and test conditions reported with the result. A lower Pusey and Jones Indentation indicates a higher Indentation Hardness. Indentation Hardness determined by this method differs from ASTM Hardness in that the latter involves precompression of rubber adjacent to the indentation whereas this method allows free plastic flow about the indentation.

### Radial Stress

The stress in the radius direction in a cylindrical material subject to a specified internal or external pressure, as in the Pressure Test. In a thin-wall specimen it is equal to the applied pressure. For rigid plastic tubing it is calculated by dividing applied load by cross section area of the cylindrical piston.

### Recovery

A measure of ability of a material to recover from deformation. A term most commonly applied to properties determined by the Compressibility and Recovery Test, the Deformation Under Load test and the Plastometer Test.

In the Compressibility and Recovery Test, it measures the extent to which a gasket material recovers from short time compressive deformation. Recovery (%) is calculated by dividing difference between recovered thickness and thickness under major load by difference between original thickness under preload and thickness under major load and multiplying by 100. It is usually reported in conjunction with Compressibility and does not indicate behavior of a material under prolonged load.

In the Deformation Under Load test, it measures the extent to which a nonrigid plastic recovers from prolonged compressive deformation occurring at an elevated temperature. Recovery (%) is calculated by dividing difference between recovered height and height after 3 hr under load by change in height under load and multiplying by 100. It is usually reported in conjunction with Method B Deformation Under Load.

In the Plastometer Test, it measures the extent to which an elastomer recovers from compressive deformation occurring at an elevated temperature. Plastometer Recovery is determined by one of two methods. In Method A the specimen is subjected to a 5-kg load at a specified temperature. At the end of the specified compression period load is released and the material is exposed to room temperature for 1 min. Specimen height is then measured in mm and this value, multiplied by 100, is known as "recovered height". Recovery (Method A) is equal to the difference between Plasticity Number and recovered height. In Method B, the specimen is compressed at the specified temperature to a spacer-controlled height of 5.0 mm and deflection and temperature are maintained for 30 sec. The specimen is then removed and allowed to recover for 5 min, at which time recovered height is determined as above. Recovery (Method B) is equal to recovered height minus 500. Plastometer Recovery is usually reported in conjunction with Plasticity Number.

See also *Rockwell Recovery*.

### Reduction of Area

A measure of Ductility of a metal. The greatest extent to which original cross section area of a specimen in the Tension Test is reduced at fracture. Reduction of Area (%) is calculated by dividing difference between original and smallest final cross section area by original cross section area and multiplying by 100. It is not determined for sheet specimens. Reduction of Area is not as widely used an index of Ductility of metals as Elongation.

### Relative Modulus

The ratio of Modulus of Rigidity of rubber at a specified low temperature to that at room temperature, as determined in the Gehman Torsional Test. The temperature at which Relative Modulus has a specified value may be determined by calculating twist angle corresponding to the specified Relative Modulus and reading the corresponding temperature from the twist-temperature curve. Twist angle corresponding to a specified Relative Modulus may be determined from tables listing corresponding values of $\theta_1$ and $\theta_2$ that satisfy the following relationship:

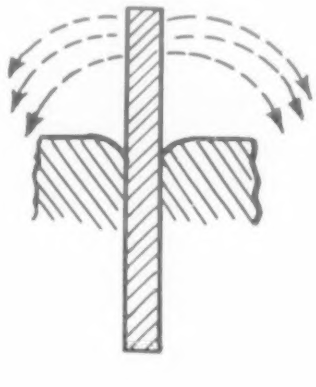
$$R.M. = \frac{\theta_1\,(180-\theta_2)}{\theta_2\,(180-\theta_1)}$$

where R.M. = specified Relative Modulus
$\theta_1$ = twist angle at room temperature, deg.
$\theta_2$ = twist angle at unknown temperature, deg.

### Repeated Bend Test

A measure of Ductility for relatively ductile metals, such

as silicon steel sheet and strip (A344-52). A specimen slightly more than 1 in. wide and at least 6 in. long is clamped at one end by a stationary jaw and at the other end by a movable jaw under sufficient spring tension to



localize the bend. The specimen is bent 90 deg and then subjected to continued 180-deg bends until a crack appears or rupture occurs. The test result is given as number of bends (including the 90-deg bend) to failure.

### Repeated Blow Impact Value

A measure of ability of a material to withstand repeated impacts without failure. A bar specimen is supported essentially as a simple beam and struck repeatedly and with gradually increasing energy by a vertical-falling hammer or pendulum until it fractures. Repeated Blow Impact Value is the height (in.) of the last drop prior to fracture. The three standard specimens (A, B and C, respectively) for cast iron (A327-50T) have diameters of 7/8, 1.2 and 2 in., and are tested with spans of 4, 6 and 12 in. and hammer weights of 12.5, 25 and 50 lb. First drop height is 2 in. and subsequent drop heights represent increments of 1 in. Unlike single-blow Impact Tests which measure total energy absorbed in sudden fracture, Repeated Blow Impact Value measures energy needed for fracture after most of the plastic deformation has occurred. See also *Drop Ball Impact Test.*

### Resilience

A measure of the elastic energy possessed by a material. The Deformation Energy of a material subjected to a specified stress or strain below that corresponding to its Proportional Limit. See also *Modulus of Resilience.*

### Rockwell Hardness

A measure of Indentation Hardness of a material. An index of resistance to surface penetration by a specified indentor under specified load. A higher Rockwell Hardness indicates a higher Indentation Hardness. For metals (E18-42) a minor load of 10 kg is applied and the dial deflection gage zeroed. The specified major load is then applied and immediately removed. Deflection is observed with minor load still on. Rockwell Hardness of metals is equal to deflection dial reading. For plastics (D785-51) and other nonmetallics, two methods are used. Method B is described under *Alpha Rockwell Hardness.* In Method A the major load is removed 15 sec after the loading lever is tripped and the lowest dial reading (corresponding to greatest penetration) occurring within 15 sec after load removal is observed. Rockwell Hardness (Method A) of plastics and glass-bonded mica is equal to dial gage reading corrected according to the number of scale revolutions involved. For hard rubber a special test is used to determine Rockwell Penetration and Rockwell Recovery. Many different loads and indentors are used to provide optimum measurements for ranges of hardness and each standard combination of load and indentor is represented by a different scale designation. Where scales overlap, Rockwell Hardness determined on one scale may be converted to Rockwell Hardness on another scale by means of a standard conversion chart. The two general types of indentor are the Brale diamond indentor, consisting of a 120-deg cone with 0.2-mm-rad spherical tip, and the steel ball indentor of 1/16 to $\frac{1}{2}$ in. dia. Scale A, with Brale indentor and 60-kg load, is suitable for tungsten carbide and other extremely hard materials on which higher loads might cause damage to the indentor. Scale B, with 1/16-in. ball and 100-kg load is suitable for materials of medium hardness such as annealed low- and medium-carbon steels. Scale C, with Brale indentor and 150-kg load, is suitable for materials harder than B100. Scale D, with only 100-kg load, is useful for materials where less penetration is desired, such as case hardened steel. Scale E, with $\frac{1}{8}$-in. ball and 100-kg load, is suitable for soft materials such as bearing metals and some plastics. Other scales used primarily for plastics are Scale R, with 60-kg load and $\frac{1}{2}$-in. ball; Scale L, with 60-kg load and $\frac{1}{4}$-in. ball; and Scale M, with 100-kg load and $\frac{1}{4}$-in. ball. Many other scales are available but not so widely used. A modification of the regular Rockwell test for metals which utilizes smaller minor and major loads is discussed under *Rockwell Superficial Hardness.*

### Rockwell Penetration

A measure of Indentation Hardness of hard rubber. An index of resistance to surface penetration by a specified indentor under specified load obtained with the Rockwell Hardness tester (D530-50T). A higher Rockwell Penetration indicates a higher Indentation Hardness. A 10-kg minor load is applied to the $\frac{1}{4}$-in. ball indentor and the deflection dial set at B30. The major load of 60 kg is then applied and held for 15 sec, at which time the dial is read. Rockwell Penetration is equal to the deflection dial reading. It is usually reported in conjunction with Rockwell Recovery.

### Rockwell Recovery

In conjunction with Rockwell Penetration of less than 200, a measure of the extent to which hard rubber recovers from indentation. After Rockwell Penetration is read from the Rockwell tester deflection dial, the major load is immediately removed and the specimen allowed to recover for 15 sec, at which time the dial is read again. Rockwell Recovery is equal to the final deflection dial reading. For a given Rockwell Penetration, a higher Rockwell Recovery indicates a greater ability to recover from indentation.

### Rockwell Superficial Hardness

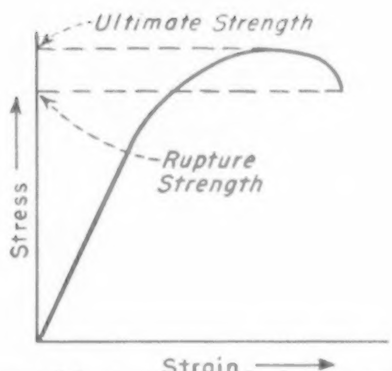
A measure of Indentation Hardness of a metal. An index of resistance to surface penetration by a specified indentor under a specified load (E18-42). A higher Rockwell Superficial Hardness indicates a higher Indentation Hardness. The test is similar to that for regular Rockwell Hardness of metals except that it utilizes lighter loads, enabling hardness of thin sections or layers, small parts and unsupported sections to be more readily evaluated. Minor load is 3 kg and major loads may be 15, 30 or 45 kg. Indentor may be Brale (designated "N") or 1/16-in. ball (designated "T"). Each of the six possible combinations of indentor and load is represented by a scale designation, e.g., 30-T.

### Ross Flexing Machine Test

A method of determining Crack Growth Resistance of rubber (D1052-52T). The specimen is a 6x1x$\frac{1}{4}$-in. rectangular strip with a 0.10-in. cut in one edge perpendicular to the flexing direction. In the Ross-Flexing Machine the strip is clamped at one end and held free between rollers at the other end in such a manner that the pierced area bends through a 90-deg angle over a 3/8-in. rod at 100 cpm. Length of the developed crack is measured frequently. The test continues until the cut is 0.6 in., representing an increase in length of 500%.

### Rupture Strength

Also called Breaking Strength. The nominal stress devel-



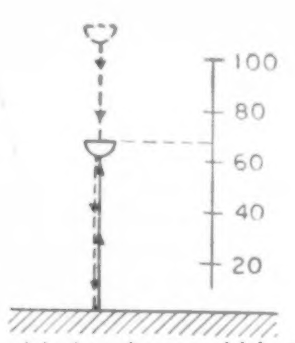

oped in a material at rupture. It is not necessarily equal to Ultimate Strength.

### St. Joe Flexometer Test

A method of determining Compression Fatigue characteristics of rubber. A specimen is placed between parallel plates at 128 F, and an axial compressive load sufficient to produce a specified vertical deflection ranging from 0.35 to 0.80 in. is applied. With specimen and plates rotating at 875 rpm a second load is applied transversely, producing a specified horizontal deflection. Frequent measurements of horizontal deflection and horizontal flexing load are made, usually until incipient failure occurs. Incipient failure in the center of the specimen is indicated by an abrupt drop in horizontal flexing load without change in horizontal deflection. Results are given as time and horizontal flexing load needed for one of several different occurrences: incipient failure; a specified vertical deflection; a specified change in vertical deflection; or complete rupture.

### Scleroscope Hardness

A measure of Hardness or Impact Resilience, primarily of metals. An index of the height of rebound of a standard diamond-tipped hammer falling freely on the part or specimen from a standard fixed height. Scleroscope Hardness




is read on an empirical scale on which 100 represents the average for quenched high-carbon steel. A higher Scleroscope Hardness indicates a higher Impact Resilience and a lower Energy Absorption. A convenient control property of somewhat limited significance and one that is greatly affected by variations in surface roughness.

### Secant Modulus of Elasticity

Also called Stress-Strain Ratio. See *Modulus of Elasticity*.

### Shear Modulus of Elasticity

Also called Modulus of Elasticity in Shear and Modulus of Rigidity. The tangent or secant Modulus of Elasticity of a material subjected to shear loading. See *Modulus of Rigidity*.

### Shear Strength

The Ultimate Strength of a material subjected to shear loading. The maximum Shear Stress that can be sustained by a material without rupture. It may be obtained from the Torsion Test, a modified Flexure Test or the Shear Test. In the Torsion Test it is equal to Torsional Strength. In the Shear Test, it is calculated by substituting maximum sustained load for P in the punch test formula for Shear Stress. It may be calculated in the Flexure Test by substituting maximum sustained load for P in the flexure formula for Shear Stress. For Shear Stress to exceed Flexural Stress in a Flexural Test, however, the span of a rectangular specimen must be less than half the square of its thickness, and the span of a cylindrical specimen must be less than one-third its diameter.

### Shear Stress

The maximum nominal biaxial stress developed by a material subjected to a specified load. In the Torsion Test, it is calculated as Torsional Stress although the assumptions underlying the formula for Torsional Stress are not valid for stresses above the Elastic Limit. In the Shear Test, Shear Stress (psi) is calculated as follows:

$$S_s = \frac{P}{\pi d t}$$

where $S_s$ = Shear Stress, psi
$P$ = punch load, lb.
$d$ = punch diameter, in.
$t$ = specimen thickness, in.

In the *Flexure Test,* Shear Stress (psi) may be calculated as follows:

$$S_s = \frac{0.75P}{bh} \text{ (for rectangular specimen)}$$

$$S_s = \frac{0.85P}{d^2} \text{ (for round specimen)}$$

where $S_s$ = maximum nominal Shear Stress, psi
$P$ = bending load, lb.
$b$ = specimen width, psi
$h$ = specimen thickness, psi
$d$ = specimen diameter, psi.

### Shear Test

A method of determining ability of a material to withstand failure when subjected to a shearing load. A small sheet or disk of known thickness with a small hole in the center is clamped over a pin on a punch of known diameter and brought into contact with the corresponding die. A gradually increasing load is then applied until the material has been completely punched through. Maximum load is observed and maximum Shear Stress or Shear Strength is calculated. For plastics (D732-46), the specimen has a cross section area of 2 sq in.

### S-N Diagram

See *Fatigue Test.*

### Softening Point

An indication of the highest practical temperature for heat-resistant hard rubber subjected to loading (D530-50T). A 4¾x½-in. rectangular strip 1/16 in. thick is supported as a simple beam, a 5-½ lb load applied at the center, and the deflection gage zeroed. Specimen temperature is then increased gradually and frequent measurements of deflection and corresponding temperature are made until deflection is so rapid that measurements are impractical. Deflection is plotted against temperature and a tangent is drawn to the linear portion of the curve. Softening Point is the temperature corresponding to the intersection of the tangent and the temperature axis.

### Splitting Resistance

A measure of ability of felt to withstand splitting (D461-51). The Tear Resistance of felt. A 6x2-in. rectangular specimen with a 2-in. longitudinal cut in its center is gripped, one lip in each of two jaws, and pulled apart. Splitting Resistance (lb) is average load needed for rupture.

### Strain

The change per unit length in a linear dimension of a body. Units: in./in. or %. Strain, as defined above and commonly used in connection with routine mechanical tests, does not indicate the natural strain actually involved. Natural strain is equal to $(\ln l/l_o)$ where l is instantaneous length and $l_o$ is original length.

### Strain Relaxation

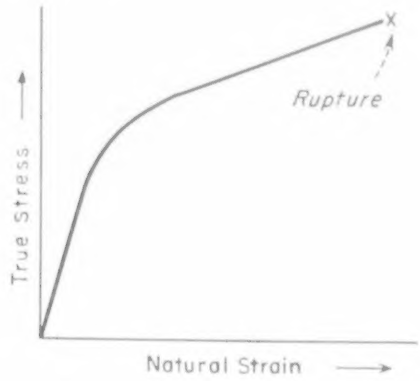
An alternate term for Creep used especially for rubber.

## Strength Reduction Ratio

See *Fatigue Notch Factor.*

## Stress

The load on a material divided by the original area of the cross-section through which it acts. Units: psi. Stress, as



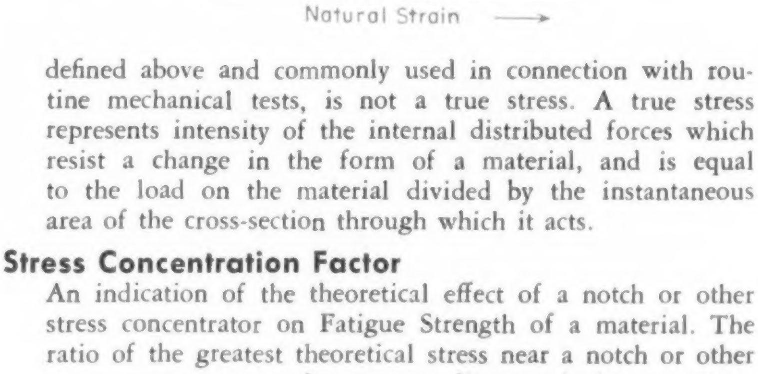

defined above and commonly used in connection with routine mechanical tests, is not a true stress. A true stress represents intensity of the internal distributed forces which resist a change in the form of a material, and is equal to the load on the material divided by the instantaneous area of the cross-section through which it acts.

## Stress Concentration Factor

An indication of the theoretical effect of a notch or other stress concentrator on Fatigue Strength of a material. The ratio of the greatest theoretical stress near a notch or other stress concentrator to the corresponding nominal stress. Theoretical stress may be determined by advanced elastic theory, by photo-elastic techniques or by direct measurement of elastic strain and use of a known stress-strain relationship. The Stress Concentration Factor is usually higher than the empirical Fatigue Notch Factor or Strength Reduction Ratio because of stress relief that occurs in conjunction with local plastic deformation. For a given material, however, a higher Stress Concentration Factor indicates a higher Fatigue Notch Factor, a lower Fatigue Strength or Endurance Limit, and a lower Fatigue Ratio.

## Stress Relaxation

The decrease in stress in a material subjected to prolonged constant strain for a specified time in a Creep Test. Stress Relaxation behavior is often presented in the form of graphs. The simplest graph is a plot of stress vs. time.



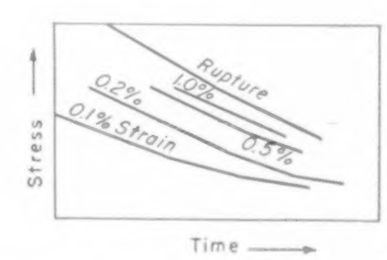

From the graph, Stress Relaxation is the difference between stress at the specified time and initial stress. Such curves can be plotted for several different constant strains at one temperature, or for several different temperatures at one constant strain, or both. From such charts can be determined, for example, the loss in bolting pressure that would be caused by Stress Relaxation over a period of several days at high temperature. Stress Relaxation Rate can also be determined.

## Stress Relaxation Rate

The rate (psi/hr) at which Stress Relaxation occurs. It is usually obtained from a log-log plot of Stress Relaxation vs. time. Stress Relaxation Rate at a specified time is equal to the slope of the tangent to the curve at that time. Average Stress Relaxation Rate over a specified period of time is equal to the difference between Stress Relaxation at the beginning and end of that period divided by the amount of time encompassed by that period. Where Stress Relaxation data are available for several different temperatures and constant strains, a graph of Stress Relaxation Rate at a specified time vs. initial stress for various temperatures is sometimes plotted. Such a graph indicates the effects of both temperature and initial stress on Stress Relaxation Rate. For any material in which Stress Relaxation occurs more slowly during an intermediate period than at the beginning or end of a test, minimum Stress Relaxation Rate can be determined by plotting Stress Relaxation Rate vs. time. For metals, minimum Stress Relaxation Rate corresponds to the slope of the approximately linear curve representing second-stage Stress Relaxation. From Stress Relaxation Rate can be predicted the decrease in stress that will occur over a specified period of time. Alone it provides no information on accumulated Stress Relaxation at any time. However, total Stress Relaxation at any time can be determined from Stress Relaxation Rate if the amount of stress corresponding to the intersection of the Stress Relaxation Rate tangent and the 0-time axis is known. It is calculated by subtracting from this stress the product of Stress Relaxation Rate and total specified time.

## Stress-Rupture Test

A method of determining ultimate load carrying ability of a material as a function of duration of loading. For plastics it is considered as part of the Creep Test. For metals (E85-50T) it is sometimes called the "rupture tension test." Specimens for both metals and plastics are similar to those




used in the Tension Test. At a specified constant temperature the specimen is subjected to a specified constant axial tensile stress or load and measurements of time and elongation made until rupture occurs. Elongation and Reduction of Area may be determined as in the Tension Test. Creep data can be developed exactly as in the Creep Test except that since initial stresses are generally higher in the Stress Rupture Test it may be necessary to distinguish not only between Creep and elastic strain but also between Creep and instantaneous plastic strain. Stress-Rupture data are often presented in the form of a semilog or log-log plot of stress vs. time for rupture. Stress-Rupture data for a specified temperature are sometimes summarized as rupture stress for 10, 100, and 1000 hr, plus Elongation at rupture. Where data for metals are available up to 2000 hr, rupture stresses for longer service times can often be determined by careful extrapolation of the approximately linear Stress-Rupture curve. Stress-Rupture curves can be plotted for several different temperatures and Stress-Rupture data for intermediate temperatures determined by interpolation, but data at temperatures beyond the test range cannot be determined by extrapolation.

## Stress-Strain Diagram

A graph on which is plotted stress vs. strain. Such a graph may be constructed in any test during which frequent or continuous measurements of both stress and strain are made. It is commonly constructed for the Compression, Tension and Torsion Tests. It is usually necessary for the determination of Deformation Energy, Elastic Limit, Modulus of Elasticity, Modulus of Rigidity, Proportional Limit and Yield Strength. It is often useful in determination of Elongation, Modulus of Rupture, Ultimate Strength and

other related properties. Analogous to the Stress-Strain Diagram are the Torque-Twist Diagram and the Load-Deflection Diagram.

### Stress-Strain Ratio
The ratio of stress to strain in a material at a specified stress or strain. Below the Elastic Limit it is also known as secant Modulus of Elasticity.

### Tangent Modulus of Elasticity
See *Modulus of Elasticity.*

### Tear Resistance
A measure of resistance of sheet or film materials to rupture by tearing. Not to be confused with Breaking Strength. A longitudinal specimen with an initial cut or notch is gripped at both ends and torn apart by one of several methods. The specimen for plastic film (D1004-49T) is a 4x3/4-in. rectangle with a deep 90-deg notch and is stretched under constant rate of extension or loading, as specified. Vulcanized rubber sheet (D624-48) is pulled apart by parallel grips and maximum load is observed. Three different specimens are used; type A is crescent-shaped with a small razor nick, type B is similar with the addition of tab ends, and type C is not nicked but is in the shape of a 90-deg angle. For plastics or vulcanized rubber, Tear Resistance (lb/in.) is calculated by dividing maximum load prior to rupture by thickness. For other materials it is usually expressed as load (lb or g) needed to tear a specified specimen. Woven (D39-49) and rubber-coated (D751-52T) fabrics may be tested by a "trapezoid" method. An isoceles trapezoid of 3-in. height and 1- and 4-in. bases is marked on a 6x3-in. rectangular specimen and a small cut is made in and perpendicular to the smaller base. The specimen is gripped along the non-parallel sides of the trapezoid and pulled apart and maximum load is observed. Woven fabrics may also be tested by the "tongue" method. A 3-in. longitudinal cut is made from one end of an 8x3-in. rectangular specimen, the two tongues are gripped and pulled apart, and maximum load is observed. Rubber-coated fabrics, untreated electrical insulating paper (D202-53T), and vulcanized fiber may be tested by the "pendulum impulse" method. The specimen is a 3x2½-in. rectangle with an 1.8-in. slit in the middle. It is gripped by one stationary jaw and one movable jaw carried on a pendulum, and a value proportional to the energy used by the pendulum to tear the specimen is indicated by a scale. Tearing load may be calculated by multiplying scale reading by 16 (for grams) or dividing scale reading by 28.6 (for pounds). See also *Splitting Resistance.*

### Tearing Strength
An alternate term for *Tear Resistance.*

### Tear-Length
A measure of drawability of metals. The height of a triangular tab torn from the edge of a metal sheet. Two small, parallel slots are cut in the edge of the sheet and perpendicular to it. The tab thus formed is gripped and torn from the sheet. The variation in the height of triangular tabs torn in different directions is an indication of crystal orientation, the tabs in the direction of orientation being longer. The extent to which this difference exists is an indication of the difficulty to be expected in drawing uniform shapes.

### Temper Test
A method of determining the relative temper of thin rolled zinc sheet (B69-39). A rectangular specimen about 5x1½ in. is inserted in a circular vise which is then rotated so that the projecting portion of the specimen is bent back against the vise mandrel by a contact arm. As the specimen passes the end of the contact arm it springs back toward its original position. Temper is reported as extent of specimen recovery indicated by a semi-circular scale graduated in percent from 0 to 100, where 100 corresponds to complete recovery. Effect of initial coil curvature is eliminated by testing two specimens in reverse positions and averaging results.

### Tensile Modulus of Elasticity
Also called Modulus of Elasticity in Tension and often merely Modulus of Elasticity. The tangent or secant Modulus of Elasticity of a material in the Tension Test. The relationship between Tensile Stress and Tensile Strain.

### Tensile Strain
The strain corresponding to a specified stress in the Tension Test.

### Tensile Strength
The Ultimate Strength of a material subjected to tensile loading. The maximum Tensile Stress developed by a material in the Tension Test. It is calculated by determining the Tensile Stress corresponding to the maximum load observed in the Tension Test. For ductile metals Tensile Strength of a material is usually greater than its Breaking Strength, but is well below the maximum true stress developed by the material. Tensile Strength is a common index for strength comparison of materials. It may be directly useful in design where some plastic deformation is permitted, but Yield Strength is the common basis for elastic design. Tensile Strength may also be some indication of allowable severity of hot and cold working processes.

### Tensile Stress
Sometimes called Modulus. The nominal stress developed by a material subjected to a specified stretching load, as in the Tension Test. Above the Elastic Limit, nominal Tensile Stress is considerably lower than the true stress because it does not reflect the decrease in cross-section area accompanying continued deformation.

### Tensile Yield Strength
The Yield Strength of a material subjected to stretch loading, as in the Tension Test. Tensile Yield Strength is usually referred to simply as Yield Strength. For metals, Tensile Yield Strength is one of the most important structural design properties and may also be some indication of relative formability. Alone, it is not a satisfactory index to the performance of a material under sudden, repeated or multiaxial loading.

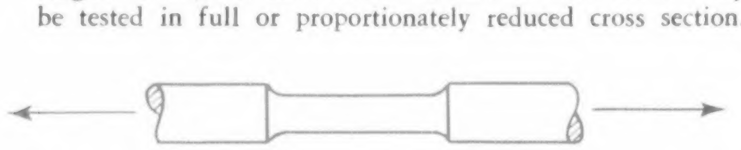
### Tension Set
The extent to which vulcanized rubber is permanently deformed after being stretched a specified amount for a short time. A Tension Test specimen is stretched slowly to produce the specified extension of a measured gage length. The extension is maintained for 10 min at which time load is released quickly and the specimen allowed to relax. Gage length is measured again 10 min after load removal. Tension Set (%) is the Permanent Set calculated by dividing difference between final and initial gage lengths by initial gage length and multiplying by 100. A special value, Tension Set at Break, is sometimes determined.

### Tension Set at Break
A special value of Tension Set. A measure of the extent to which vulcanized rubber is permanently deformed at rupture in a Tension Test. The two pieces of the ruptured specimen are allowed to rest 10 min, at which time they are fitted together and final gage length is measured. Tension Set at Break (%) is Permanent Set calculated in the same way as Tension Set.

### Tension Test
A method of determining behavior of a material subjected to axial stretch loading. A longitudinal specimen with a reduced section of known diameter and measured gage length is gripped at both ends and stretched at a slow, controlled rate of extension to rupture. Usually, frequent or continuous measurements of load and extension are made, Tensile Stress and Strain calculated and a Stress-Strain Dia-

gram constructed. From the test and the diagram may be calculated Elastic Limit, Elongation, Modulus of Elasticity, Proportional Limit, Reduction of Area, Tensile Strength, Yield Point, Yield Point Elongation and Yield Strength. For metals, the Tension Test is sometimes conducted at elevated temperatures up to 2000 F (E21-43). Plastics are tested at both subnormal and supernormal temperatures (D759-48). Specimens for metals vary widely, depending


on size and form of the material. The three most common are the flat plate specimen with $1\frac{1}{2}$-in.-wide reduced section and 8-in. gage length, the flat sheet specimen with $\frac{1}{2}$-in.-wide reduced section and 2-in. gage length, and the round specimen with a slightly tapered $\frac{1}{2}$-in.-dia reduced section and 2-in. gage length (E8-52T). Proportionate round bars of different sizes are sometimes used. Round wire and rod are usually tested in full cross section with 10-in. gage length. Wire, rod and bar of non-circular cross section may be tested in full or proportionately reduced cross section.



Tube may be tested full size or by means of a cut-out flat or round specimen. Various modified round specimens are used for cast iron, malleable iron and die castings. For electrical porcelain (D116-44) the specimen is cylindrical with a straight reduced section 1 in. long and $1\frac{1}{8}$-in. dia tapering up to an overall diameter of slightly more than $1\frac{3}{4}$ in. Specimens for plastic sheet, plate and moldings (D638-52T) and compression-molded glass-bonded mica are rectangular blocks of various widths. The specimen for sheet electrical insulating material (D229-49) is rectangular with a section of reduced width. Specimens for rigid or laminated (D348-52) tube and laminated rod (D349-52) have a straight reduced section $2\frac{1}{4}$ in. long where wall thickness or diameter is 60% of the nominal. The flat specimen for injection-molded glass-bonded mica and other molded electrical insulating materials (D651-48) has a section reduced in both width and thickness. Thin plastic sheet and film (D882-49T) may be tested either at constant extension rate or at constant loading rate, as specified. The specimen is rectangular, about 3-4 in. long and 3/16 to 1 in. wide. A correction must be applied to extension measurements made under constant loading rate. Breaking Strength is sometimes reported rather than Tensile Strength. For vulcanized rubber (D412-51T) and the larger sizes of nonrigid polyvinyl tubing (D876-52T), a flat rectangular, dumbbell or ring specimen may be used. The dumbbell specimen has a straight reduced section usually about $1\frac{1}{4}$ in. long. The ring specimen is looped over rollers for the test. The smaller sizes of nonrigid polyvinyl tubing are tested as tubing. The hard rubber specimen (D530-50T) is flat and rectangular with a 3-in. straight reduced section $\frac{1}{2}$-in. wide. Ordinarily, only Tensile Strength and Elongation are determined for rubber. A dumbbell specimen with a reduced section about $2\frac{1}{4}$ in. long is generally used for compressed asbestos sheet (D733-53T).

## Tension-Impact Test

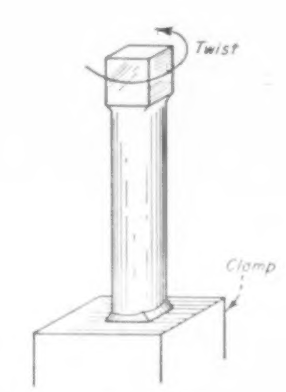
An Impact Test for determination of Energy Absorption in fracture of a material. A cylindrical specimen with a reduced section is supported at one end and ruptured by a sudden axial tensile load applied to the other end. The apparatus may be arranged so that the specimen is fixed to the pendulum and the free end catches on stationary supports, or so that the specimen is held by stationary supports and its free end is caught by the pendulum. Test results must be adjusted to account for energy dissipated in moving auxiliary fixtures. A variety of specimens are used (E23-47T). The reduced section may be straight and relatively long (Types T and V) as in the Tension Test; extremely short, amounting to a notch (Types W and U); or intermediate in length and tapered to a minimum diameter at the center (Type X).

## Torque-Twist Diagram

A graph on which is plotted torque (in.-lb.) vs. corresponding Torsional Deformation as measured in the Torsion Test. It is usually necessary for determination of Permanent Torsional Deformation and is often useful in determination of Maximum Torsional Deformation. Other torsional properties are more readily determined from a Stress-Strain Diagram which may be constructed from a Torque-Twist Diagram by substituting equivalent Torsional Stress for torque and equivalent Torsional Strain for Torsional Deformation.

## Torsion Test

A method of determining behavior of a material subjected to twisting loads. A cylindrical specimen with a straight reduced section and longitudinal gage mark is twisted axially to rupture. For cast iron (A260-47) the straight reduced section is $\frac{3}{4}$ in. dia and about 5 in. long. Sometimes a thin-wall tubular specimen is preferred since stress can then be assumed to be essentially constant throughout the cross section. Frequent measurements of torque and total angle of twist are made during the test, and values of Torsional Deformation corresponding to total angles of twist are determined. A Torque-Twist Diagram may be plotted




or an analogous Stress-Strain Diagram derived from these measurements. Properties that can be determined from the Torsion Test include Elastic Limit, Maximum Torsional Deformation, Modulus of Elasticity (or Modulus of Rigidity), Proportional Limit, Torsional Strength, Yield Point and Yield Strength. The Torsion Test is sometimes used in preference to the Tension Test for brittle materials. It is required by few specifications. For large strains, torsion data are considered more valid than tension data and torsion data are often used in the solution of certain mechanical design problems involving shear loading. A special limited Torsion Test may be used to determine an Apparent Modulus of Rigidity for plastics. See also *Twisting Test.*

## Torsional Deformation

The angular twist of a specimen produced by a specified torque in the Torsion Test. Torsional Deformation (radians/in.) is calculated by dividing observed total angular twist (the twist of one end of the gage length with respect to the other) by original gage length.

## Torsional Deformation, Maximum

A measure of the greatest extent to which a material can be twisted without rupture. The Torsional Deformation at rupture in the Torsion Test.

## Torsional Deformation, Permanent

Also called Permanent Angle of Twist. The Torsional Deformation that remains when load is completely removed

from a specimen subjected to a specified torque in the Torsion Test. The Permanent Set in Torsion. On a Torque-Twist Diagram it is equal to the intersection with the Torsional Deformation axis of a line drawn through the curve at the specified torque and parallel to the straight-line portion of the curve.

**Torsional Modulus of Elasticity**
Also called Modulus of Elasticity in Torsion, Shear Modulus of Elasticity, Modulus of Elasticity in Shear and Modulus of Rigidity. See *Modulus of Rigidity*.

**Torsional Strain**
The strain corresponding to a specified torque or Torsional Stress in the Torsion Test. It is calculated by multiplying Torsional Deformation by specimen radius (in.).

**Torsional Strength**
Also called Modulus of Rupture in Torsion and, sometimes, Shear Strength. A measure of the ability of a material to withstand a twisting load. The Ultimate Strength of a material subjected to torsional loading, as in the Torsion Test. The maximum Torsional Stress that can be sustained by a material without rupture. It is calculated from the formula for Torsional Stress where T is maximum torque. For a part of known dimensions, maximum allowable torque can be calculated from Torsional Strength by means of the same formula.

**Torsional Stress**
The Shear Stress developed by a material subjected to a specified torque in the Torsion Test. It is calculated as follows:

$$S = \frac{Tc}{J}$$

where $S$ = Torsional Stress, psi
$T$ = torque, in.-lb.
$c$ = distance from axis of twist to outermost fiber of specimen, in.
$J$ = polar moment of inertia, in.$^4$

For solid cylindrical specimens, $J = 1/32\ \pi\ d^4$, where d is diameter (in.) and the formula is:

$$S = \frac{16\,T}{\pi\, d^3}$$

For tubular specimens, $J = 1/32\ \pi\ (d_2^4 - d_1^4)$, where $d_2$ is outer diameter and $d_1$ is inner diameter, and the formula is:

$$S = \frac{16\,T\,d_2}{\pi\,(d_2^4 - d_1^4)}$$

For cast iron, where the specimen has been standardized, the formula can be simplified as follows:

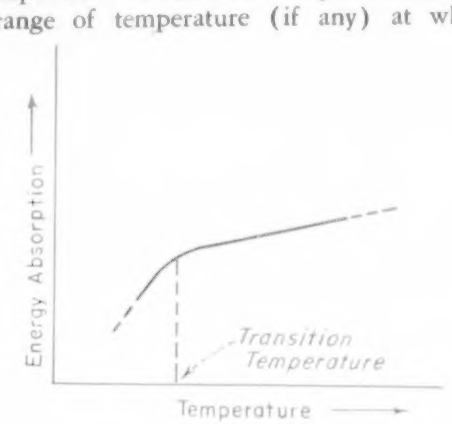
$$S = 12.1\,T$$

Torsional Stress as calculated above is not a true stress above the Proportional Limit, since the formula assumes proportionality of stress and strain, but it is accepted as practical and convenient.

**Torsional Yield Strength**
The Yield Strength of a material subjected to twist loading, as in the Torsion Test. An offset of 0.001 radians/in. (0.0375% for a ¾-in. specimen) is standard for cast iron.

**Toughness**
The resistance of a material to failure under dynamic loading conditions. A property most commonly represented by Energy Absorption measured in an Impact Test. A higher Energy Absorption indicates a greater Toughness. The term "notch Toughness" may also refer to effect of a notch on fatigue properties. A higher Fatigue Notch Factor indicates a greater notch Toughness.

**Transition Temperature**
The temperature or approximate temperature range above which certain steels exhibit ductile fracture and below which they exhibit brittle fracture in an Impact Test. Energy Absorption is determined for a series of temperatures, usually in the normal atmospheric range, and plotted against temperature. Transition Temperature is the temperature or range of temperature (if any) at which Energy

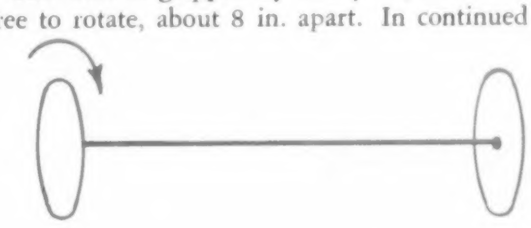



Absorption drops suddenly. Maximum Transition Temperature is sometimes specified for control or acceptance of ferritic steels which are particularly susceptible to this temperature effect.

**Transverse Bend Test**
An alternate term for Flexure Test employed particularly with cast iron. Not to be confused with Bend Test.

**Twist, Maximum or Permanent**
See *Torsional Deformation (Maximum or Permanent)*.

**Twisting Test**
A method of determining relative strength and Ductility of wire. Either "continued" or "reversed" torsion may be used. The wire is gripped by two jaws, one stationary and one free to rotate, about 8 in. apart. In continued twisting,



the movable jaw is rotated until the wire fractures and number of rotations is reported. In reversed twisting, the movable jaw is rotated back and forth a specified amount until the wire fractures and the number of forward and reverse twists is reported.

**Ultimate Elongation**
An alternate term for Elongation of a material at rupture in the Tension Test.

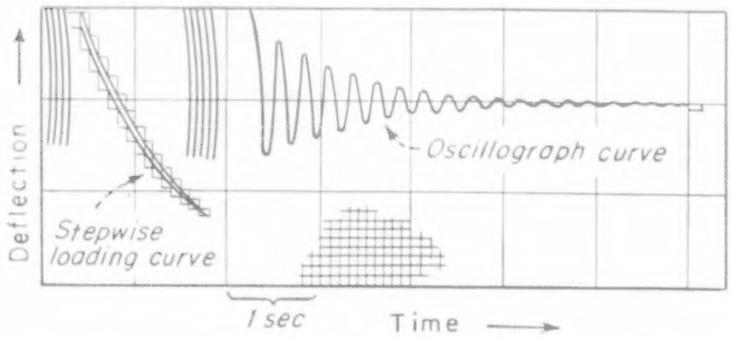
**Ultimate Strength**
The nominal maximum stress that can be sustained without rupture by a material subjected to a specified type of loading. It may be Compressive Strength, Flexural Strength, Shear Strength, Tensile Strength or Torsional Strength. Where type of loading is not specified, it usually refers to Tensile Strength.

**Vickers Hardness**
See *Diamond Pyramid Hardness*.

**Wrapping Diameter**
A measure of Ductility or windability of wire. The minimum diameter upon which metal wire can be wound without fracture.

**Yerzley Mechanical Oscillograph Test**
A method of determining certain mechanical properties of vulcanized rubber that are useful in selection and design of materials for vibration absorption (D945-52T). Either compression or shear loading may be used. The compression specimen is a disk about ¾ in. dia and ½ in. thick. The shear specimen is a rectangular sandwich consisting of two blocks about ½x½x⅞ in. adhered between projecting metal plates (shear load is applied transversely to the edge of the center metal plate). The specimen is loaded through the short arm of a balance lever, the long end of which is connected to a pen that records deflection

on a chronograph chart marked off in 1/10-in. squares. Load is applied by means of a series of weights (each producing a force of 8.82 lb on the specimen) added to the



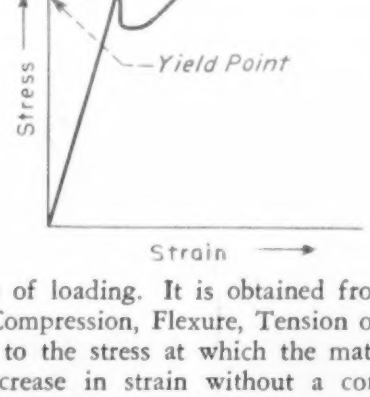

pen arm of the beam. The specimen is conditioned by deforming it about 30% by hand three times. A static loading graph is obtained by adding the weights one at a time and advancing the chronograph by hand one small division (a double scale is used for shear) after each weight except the last. After 50% deflection is reached, the chart is reversed one division and all weights removed one at a time, the chronograph being reversed one division after each removal. From the stepwise graph may be constructed a Load-Deflection Diagram. The number of weights needed to produce 20% deformation is estimated from the stepwise curve and the beam (disengaged from the specimen) loaded accordingly. Equilibrium is checked by engaging the loaded beam several times until a vertical deflection line of reproducible length is produced on the graph. The chronograph is then set in rotation at 1 in./sec, the full load engaged once more, and the resulting oscillograph curve recorded. Sometimes Permanent Set is measured at the conclusion of the test. From the Load-Deflection Diagram and the oscillograph curve can be calculated Creep, Deformation Energy, Effective Dynamic Modulus, Kinetic Energy in Elastomeric Spring, Static Modulus, and Yerzley Resilience.

### Yerzley Resilience

A measure of elasticity of rubber obtained from the Yerzley Mechanical Oscillograph Test. Yerzley Resilience (%) is calculated by dividing vertical height of rebound of the first cycle of the oscillograph curve by vertical height of fall in the first cycle.

### Yield Point

An indication of the maximum stress that can be sustained without plastic deformation by a material subjected to a



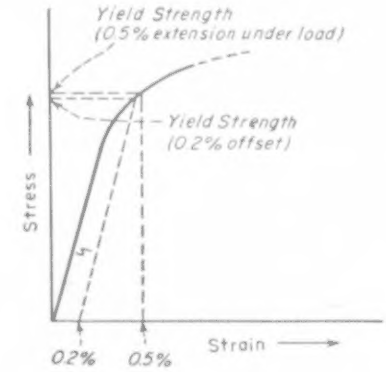

specified type of loading. It is obtained from a static test, such as the Compression, Flexure, Tension or Torsion Test, and is equal to the stress at which the material undergoes a marked increase in strain without a corresponding increase in stress. On a Stress-Strain Diagram, Yield Point is indicated by the top of a sharp "knee" portion in the curve. Load corresponding to Yield Point can also be determined from observations of loading or straining behavior during the test itself. In the "drop of beam" method, the machine operator runs the load poise out slightly beyond the balance position. At Yield Point load the beam drops for a brief but observable period of time. With self-indicating load-measuring equipment, Yield Point load is marked by a sudden halt of the load-indicating pointer. Yield Point is also the load at which there is a sudden increase in rate of Elongation as shown with dividers on the gage length or by means of an extensometer. The Yield Point most commonly determined is Yield Point in the Tension Test for steels. Many materials do not exhibit the Yield Point phenomenon. For such materials, Yield Strength is the closest comparable property.

### Yield Point Elongation

A measure of Ductility of a material. The strain or Elongation corresponding to the Yield Point.

### Yield Strength

A measure of resistance to plastic deformation of a material subjected to a specified type of loading. The stress at which a material exhibits a specified limiting permanent deformation. A practical approximation of Elastic Limit. Yield Strength is usually determined by one of two common methods: "offset" or "strain under load". Offset Yield Strength is determined from a Stress-Strain Diagram; it is




the stress corresponding to the intersection with the curve of a line that is parallel to the straight-line portion of the curve and intersects the 0-stress axis at a strain equal to a specified offset. Offset is usually specified as 0.2%. Where stress-strain behavior of a material is known, Yield Strength may be given as the stress corresponding to a specified strain, a quantity that can be determined by direct measurement and without a Stress-Strain Diagram. This method is used primarily in determining Tensile Yield Strength of copper and copper alloys. Specified deformation is 0.5% extension under load which corresponds to an offset of about 0.35%. Without a Stress-Strain Diagram, however, Yield Strength at a specified offset cannot be compared with Yield Strength at a specified strain under load with any degree of certainty. Yield Strength may also be determined as the stress required to produce a specified Permanent Set, but this method involves trial-and-error procedure and is seldom used. Depending on type of loading involved, Yield Strength may be known as Compressive Yield Strength, Flexural Yield Strength, Shear Yield Strength, Tensile Yield Strength or Torsional Yield Strength. Yield Strength, alone, is generally assumed to refer to Tensile Yield Strength.

### Yield Strength Elongation

A measure of Ductility of a material. The strain or Elongation corresponding to the Yield Strength.

### Young's Modulus

An alternate term for Modulus of Elasticity.

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# Materials Engineering File Facts

## Properties of Free Cutting Steels

These steels are particularly adapted to automatic screw machine production of small repetitive parts. The ideal application is one where bulk and shape, as dictated by design, are the chief requirements.

| AISI Grade | Nominal Properties | | |
|---|---|---|---|
| | B-1111 C-1211 | B-1112 C-1212 | B-1113 C-1213 |
| **COMPOSITION—%** | C 0.13 max<br>Mn 0.60/0.90<br>P 0.07/0.12<br>S 0.08/0.15 | C 0.13 max<br>Mn 0.70/1.00<br>P 0.07/0.12<br>S 0.16/0.23 | C 0.13 max<br>Mn 0.70/1.00<br>P 0.07/0.12<br>S 0.24/0.33 |
| **PHYSICAL PROPERTIES** | | | |
| Density, Lb/Cu In. | 0.283 | 0.283 | 0.283 |
| Thermal Cond, Btu/Hr/Sq Ft/Ft/F, @ 212 F | 27 | 27 | 27 |
| Coeff of Exp per F: 70–1200 F | $8.4 \times 10^{-6}$ | $8.4 \times 10^{-6}$ | $8.4 \times 10^{-6}$ |
| Spec Ht, Btu/Lb/F: | 0.10–0.11 | 0.10–0.11 | 0.10–0.11 |
| Elect Res, Microhm-Cm @ 68 F | 14.3 | 14.3 | 14.3 |
| **MECHANICAL PROPERTIES** | | | |
| Mod of Elasticity in Tension, Psi | $29 \times 10^6$ | $29 \times 10^6$ | $29 \times 10^6$ |
| Tensile Str, 1000 Psi: | | | |
| Cold Drawn 9/16-in. dia | 85/110 | 85/110 | 85/110 |
| 1-in. dia | 80/105 | 80/105 | 80/105 |
| 2-in. dia | 70/90 | 70/90 | 70/90 |
| Yield Str, 1000 Psi: | | | |
| Cold Drawn 9/16-in. dia | 75/100 | 75/100 | 75/100 |
| 1-in. dia | 70/90 | 70/90 | 70/90 |
| 2-in. dia | 60/85 | 60/85 | 60/85 |
| Elongation in 2 in., %: | | | |
| Cold Drawn 9/16-in. dia | 10/20 | 10/20 | 10/20 |
| 1-in. dia | 12/22 | 12/22 | 12/22 |
| 2-in. dia | 10/20 | 10/20 | 10/20 |
| Reduction of Area, %: | | | |
| Cold Drawn 9/16-in. dia | 30/50 | 30/50 | 30/50 |
| 1-in. dia | 35/55 | 35/55 | 35/55 |
| 2-in. dia | 30/50 | 30/50 | 30/50 |
| Hardness, Bhn: | | | |
| Cold Drawn 9/16-in. dia | B90/B102[1] | B90/B102[1] | B90/B102[1] |
| 1-in. dia | 163/229 | 163/229 | 163/229 |
| 2-in. dia | 149/202 | 149/202 | 149/202 |
| Impact Str | These grades have relatively low impact strength at low temperature and should not be used for shock loading applications at sub-zero temperatures. | | |
| Fatigue Str (End Limit) | As cold-drawn, these steels are notch-sensitive. Polished fatigue specimens will show expected values but poor finishing or processing of parts may cause low and erratic results for finished parts under dynamic or alternating stresses of relatively low intensity. | | |
| **THERMAL TREATMENT** | | | |
| Case Hardening Temp, F (Quench in water or oil) | 1450/1700 | 1450/1700 | 1450/1700 |
| Tempering Temp, F | 300 | 300 | 300 |
| | These grades case hardened for high surface hardness and good wear resistance where core properties are not important. Case hardness Rockwell C 60–C 65. | | |
| **FABRICATING PROPERTIES** | These steels not recommended for operations involving cold metal movement such as crimping, forming or bending. | | |
| Machinability Index | 90 | 100 | 125 |
| Speed, SFM average | 153 | 170 | 213 |
| **AVAILABLE FORMS** | Cold drawn shapes. | | |
| **USES** | Studs, nuts, fasteners, sleeves, collars, spacers, dowels, rods, handles, levers, etc. | | |

*Notes:*

*B1111, B1112, B1113 are Bessemer Steels.*
*C1211, C1212, C1213 are basic open hearth steels.*
[1] *Rockwell Hardness Number.*

*Prepared with the assistance of Bliss & Laughlin, Inc.*

# TUBING MACHINABILITY


Machinability of tubing is vitally important to producers of hollow cylindrical parts. But in the last analysis, final production *cost* is the real determining factor. Consequently, choosing the mechanical tubing that will easily machine to the quality finished part you demand and also hold final cost to the minimum, requires careful consideration of all the factors involved.

Matching the tubing to your own product needs and production equipment is important. Getting — in the tube — as many as possible of the characteristics and properties desired in the finished part, is equally important. Finish, heat treatment, tolerances, steel quality, alloy factor—any or all of these can be supplied within the original B&W mechanical tubing, to either eliminate or to reduce your machining and other production operations.

Because B&W mechanical tubing is tailor-made to suit your combination of production conditions and product specifications, you win on all counts. You'll find that the machining characteristics of the B&W tubing you select make it particularly suitable for your type of machine tool. Since you start with the desired properties, your production time and costs are pared to the bone.

B&W Regional Sales Offices, together with a nationwide network of B&W Distributors, are always prepared to serve you. You'll find Mr. Tubes — your link to B&W—always available to provide unbiased assistance in meeting your specific mechanical tubing requirements.

**THE BABCOCK & WILCOX COMPANY**
***TUBULAR PRODUCTS DIVISION***
**Beaver Falls, Pa.— Seamless Tubing; Welded Stainless Steel Tubing**
**Alliance, Ohio — Welded Carbon Steel Tubing**

B&W SEAMLESS and WELDED TUBES

TA-4025(M)

For more information, turn to Reader Service Card, Circle No. 311

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# Strengths of American Woods

Wood has a number of qualities to recommend it. It is readily workable with simple tools and can be cut at high speeds with low power consumption by machine tools. On the average, wood is about ¼ as heavy as magnesium, the lightest structural metal. It has good strength particularly under compression loading. The greatest disadvantage of wood is its tendency to change moisture content with resulting dimensional changes. Other disadvantages, common to natural organic products are lack of uniformity, poor abrasion resistance and highly directional strength.

The tensile strength of a piece of wood parallel to the grain is about 40 times that perpendicular to the grain. Compressive strength parallel to the grain is three to ten times that perpendicular to the grain. Because of these directional properties, it is necessary to consider the relationship between direction of application of the load and grain direction of the wood in designing.

| | Spec Gravity | Static Bending Stress at Prop Limit, psi | Compression, Max Crushing Str | |
|---|---|---|---|---|
| | | | Parallel to Grain, psi | Perpendicular to Grain, psi |
| White Ash | 0.60 | 8900 | 7410 | 1410 |
| Basswood | 0.37 | 5900 | 4730 | 450 |
| Beech | 0.64 | 8700 | 7300 | 1250 |
| Yellow Birch | 0.62 | 10,100 | 8170 | 1190 |
| Cottonwood, northern black | 0.35 | 5300 | 4420 | 370 |
| Elm, rock | 0.63 | 8000 | 7050 | 1520 |
| Sweet Gum, red | 0.49 | 8100 | 5800 | 860 |
| Tupelo Gum | 0.50 | 7200 | 5920 | 1070 |
| Hickory, bigleaf shagbark | 0.69 | 8900 | 8000 | 2220 |
| Black Locust | 0.69 | 12,800 | 10,180 | 2260 |
| Maple, Sugar | 0.63 | 9500 | 7830 | 1810 |
| Oak, White | 0.68 | 8200 | 7440 | 1320 |
| Oak, Red | 0.63 | 8400 | 6920 | 1260 |
| Poplar, Yellow | 0.40 | 6100 | 5290 | 580 |
| Black Walnut | 0.55 | 10,500 | 7580 | 1250 |
| Willow, Black | 0.37 | 3900 | 3420 | 480 |
| Cedar, Port Orford | 0.42 | 7700 | 6470 | 760 |
| Cedar, Eastern Red | 0.47 | 3800 | 6020 | 1140 |
| Cypress Southern (bald) | 0.46 | 7200 | 6360 | 900 |
| Douglas Fir (coast type) | 0.48 | 8100 | 7420 | 910 |
| Balsam Fir | 0.36 | 5200 | 4530 | 380 |
| Hemlock (eastern) | 0.40 | 6100 | 5410 | 800 |
| Hemlock (western) | 0.42 | 6800 | 6210 | 680 |
| Pine, eastern white (northern white) | 0.36 | 6000 | 4840 | 550 |
| Pine, Longleaf | 0.58 | 9300 | 8440 | 1190 |
| Pine, Ponderosa | 0.40 | 6300 | 5270 | 740 |
| Redwood (virgin) | 0.40 | 6900 | 6150 | 860 |
| Spruce, Sitka | 0.40 | 6700 | 5610 | 710 |

*Samples were air-dried to 12% moisture content (selected from Markwardt and Wilson, U. S. Dept. of Ag., Tech. Bulletin 479, 1935).*

# How this "S" Monel Sleeve...

# costs Con Edison <u>less</u> than plain water!

**"Machined in the Mold."** All the machining required to form the three steps on this "S" Monel shaft was eliminated by Inco casting specialists. They turned the trick in the centrifugal mold itself by using a special carbon insert. Result: a shaft sleeve with three different outside diameters and a constant inside diameter — *as cast!*

At Consolidated Edison's East River Station, they used to replace shaft sleeves in the circulating pumps within 2½ years — often sooner.

And you can easily understand why. New York's East River is both salty and sandy. Besides, two sewer trunks empty into the river less than 300 feet from the pump intake. When that gritty, brackish water gets in the gland seals, abrasion and corrosion go right to work on the sleeves.

Con Edison's maintenance engineers considered using fresh water in the packing gland. The cost of the water practically ruled this out. Then they compared the cost of "S" Monel sleeves with the price of those they had been using. If "S" Monel sleeves lasted long enough in the salt water, they'd more than pay their own way. *It was worth a try.*

Did the "S" Monel sleeves work out satisfactorily? Here's the answer in Con Edison's own words:

*"The first of our 'S' Monel sleeves was installed in 1949. The extra cost of a new 'S' Monel sleeve—installed—is less than the added cost of supplying plain water to the gland."*

Perhaps an Inco Casting—or an Inco Nickel Alloy — can solve a costly service problem for you. Our 16-page booklet, *Standard Alloys for Special Problems,* is designed to help you select the Inco Nickel Alloy best suited to withstand destructive service conditions. Write us for a free copy.

**The International Nickel Company, Inc.**
67 Wall Street New York 5, N. Y.

INCO
TRADE MARK

**MONEL® • "R"® MONEL • "K"® MONEL**
**"KR"® MONEL • "S"® MONEL • INCONEL®**
**INCONEL "X"® • INCONEL "W"®**
**INCOLOY® • NIMONIC® Alloys • NICKEL**
**LOW CARBON NICKEL • DURANICKEL®**

# Inco Nickel Alloys

For more information, turn to Reader Service Card, Circle No. 324

## Nominal Compositions of Typical High Strength Heat Resisting Alloys and Limited Stress Rupture Data

| Alloy | Chemical Compositions by Weight, % | | | | | | | | | | | Stress to Rupture psi x 1000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | Co | Ni | Fe | Cr | Mo | W | Cb/Ta | Ti | Al | Other | 100 Hr | 1000 Hr |
| CAST ALLOYS | | | | | | | | | | | | at 1500 F | |
| 61 (HS23) | 0.40 | 68.0 | 1.0 | 2.0 | 24.0 | — | 5.0 | — | — | — | — | 27.0 | 21.0 |
| HS21 | 0.25 | 62.0 | 2.0 | 1.0 | 27.0 | 6.0 | — | — | — | — | — | 22.0 | 16.0 |
| X63 (GE) | 0.40 | 56.0 | 10.0 | 3.0 | 23.0 | 6.0 | — | — | — | — | — | 26.0 | 20.0 |
| X40 (HS31) | 0.50 | 55.0 | 10.0 | 1.0 | 25.0 | — | 7.0 | — | — | — | — | 28.0 | 23.0 |
| L-251 | 0.40 | 54.0 | 10.0 | 1.0 | 19.0 | — | 14.0 | — | — | — | — | 28.0 | 23.0 |
| 422-19 (HS30) | 0.40 | 50.0 | 15.0 | 1.0 | 26.0 | 6.0 | — | — | — | — | — | 27.0 | 21.0 |
| 6059 (HS27) | 0.40 | 34.0 | 33.0 | 1.0 | 25.0 | 6.0 | — | — | — | — | — | 23.0 | 18.0 |
| Refractaloy 80 | 0.10 | 30.0 | 20.0 | 14.0 | 20.0 | 10.0 | 5.0 | — | — | — | — | 19.0 | — |
| HE-2048 | 0.40 | 15.0 | 30.0 | 21.0 | 26.0 | 4.0 | 2.0 | — | — | — | 0.15 B | 20.0 | 14.0 |
| Hastelloy C | 0.10 | — | 56.0 | 6.0 | 16.0 | 16.0 | 4.0 | — | — | — | 0.3 V | 18.0 | 13.0 |
| 1-1360 | 0.10 | — | 70.0 | 6.0 | 10.0 | 5.0 | — | 2.0 | — | 6.0 | 0.5 Be | 45.0 | 32.0 |
| 95-M-255 | — | — | 67.0 | 1.0 | — | 25.0 | — | — | — | 6.0 | — | — | — |
| WROUGHT ALLOYS TYPE I | | | | | | | | | | | | at 1500 F | |
| L-605 | 0.05 | 53.0 | 10.0 | 1.0 | 20.0 | — | 15.0 | — | — | — | — | 24.0 | 17.0 |
| I-336 | 0.20 | 50.0 | 15.0 | 1.0 | 20.0 | — | 12.0 | 1.0 | — | — | — | 25.0 | 17.0 |
| WF31 | 0.15 | 50.0 | 10.0 | 5.0 | 20.0 | 3.0 | 10.0 | — | — | — | — | 24.0 | 17.0 |
| S-844 (V. 36) | 0.30 | 44.0 | 20.0 | 2.0 | 25.0 | 3.0 | 2.0 | 2.0 | — | — | — | 23.0 | 16.0 |
| S-816 | 0.40 | 43.0 | 20.0 | 3.0 | 20.0 | 4.0 | 4.0 | 4.0 | — | — | — | 24.0 | 18.0 |
| 25 Ni | 0.15 | 40.0 | 25.0 | 2.0 | 19.0 | — | 11.0 | 1.0 | — | — | — | 27.0 | 22.0 |
| Refractory | 0.05 | 30.0 | 21.0 | 14.0 | 20.0 | 8.0 | 4.0 | — | — | — | — | 19.0 | 15.0 |
| S-590 | 0.40 | 20.0 | 20.0 | 25.0 | 20.0 | 4.0 | 4.0 | 4.0 | — | — | — | 19.0 | 15.0 |
| N-155 (CW) | 0.10 | 20.0 | 20.0 | 32.0 | 20.0 | 3.0 | 2.0 | 1.0 | — | — | 0.15 B | 18.0 | 13.0 |
| Hastelloy X | 0.10 | 2.0 | 48.0 | 18.0 | 21.0 | 9.0 | 1.0 | — | — | — | — | — | — |
| CSA 39 | 0.10 | — | 27.0 | 40.0 | 19.0 | 9.0 | 3.0 | — | — | — | — | 20.0 | 15.0 |
| Hastelloy B | 0.10 | — | 66.0 | 5.0 | — | 28.0 | — | — | — | — | 0.3 V | 17.0 | 11.0 |
| WROUGHT ALLOYS TYPE II | | | | | | | | | | | | at 1500 F | |
| K-42-B | 0.05 | 22.0 | 42.0 | 14.0 | 18.0 | — | — | — | 3.0 | R | — | 22.0 | 15.0 |
| Refractaloy 26 | 0.05 | 20.0 | 37.0 | 17.0 | 18.0 | 3.0 | — | — | 3.0 | R | — | 29.0 | 18.0 |
| Nimonic 90 | 0.05 | 20.0 | 54.0 | 1.0 | 20.0 | — | — | — | 2.0 | 1.0 | — | 28.0 | 18.0 |
| Waspaloy | 0.05 | 13.0 | 58.0 | 1.0 | 20.0 | 3.0 | — | — | 2.0 | 1.0 | — | 28.0 | 18.0 |
| M-252 | 0.10 | 10.0 | 53.0 | 3.0 | 19.0 | 10.0 | — | — | 2.0 | 1.0 | — | 26.0 | 17.0 |
| Nimonic 80 A | 0.05 | 1.0 | 73.0 | 1.0 | 20.0 | — | — | — | 2.0 | 1.0 | — | 19.0 | 11.0 |
| Inconel X | 0.05 | 1.0 | 71.0 | 7.0 | 15.0 | — | — | 1.0 | 2.0 | 1.0 | — | 28.0 | 18.0 |
| INTERMEDIATE ALLOYS | | | | | | | | | | | | at 1200 F | |
| G-18-B (CW) | 0.40 | 10.0 | 13.0 | 53.0 | 14.0 | 2.0 | 3.0 | 3.0 | — | — | — | 48.0 | 35.0 |
| 16-25-6 (CW) | 0.10 | — | 25.0 | 51.0 | 16.0 | 6.0 | — | — | — | — | 0.15N | 50.0 | 38.0 |
| Discaloy | 0.05 | — | 25.0 | 55.0 | 13.0 | 3.0 | — | — | 2.0 | R | — | 55.0 | 42.0 |
| A-286 | 0.05 | — | 26.0 | 53.0 | 15.0 | 1.0 | — | — | 2.0 | R | 0.3 V | 62.0 | 45.0 |
| 17W (CW) | 0.50 | — | 19.0 | 63.0 | 13.0 | 1.0 | 2.0 | — | — | — | — | — | — |
| HS-88 (CW) | 0.10 | — | 15.0 | 69.0 | 12.0 | 2.0 | 0.5 | — | — | — | 0.1 B | 52.0 | 42.0 |
| 19-9-DL (CW) | 0.30 | — | 9.0 | 68.0 | 19.0 | 1.0 | 1.0 | 3.0 | — | — | — | 50.0 | 40.0 |
| OTHER JET ENGINE ALLOYS | | | | | | | | | | | | at 1200 F | |
| Inconel | 0.05 | — | 78.0 | 7.0 | 14.0 | — | — | — | — | — | — | 22.0 | 15.0 |
| AISI 310 | 0.10 | — | 20.0 | 53.0 | 25.0 | — | — | — | — | — | — | 25.0 | 18.0 |
| AISI 321 | 0.06 | — | 10.0 | 70.0 | 18.0 | — | — | — | 0.5 | — | — | 29.0 | 18.0 |
| Crucible 422 | 0.20 | — | 1.0 | 82.0 | 13.0 | 1.0 | 1.0 | — | — | — | 0.3 V | 25.0 | 17.0 |
| H-40 | 0.25 | — | R | 93.0 | 3.0 | 0.5 | 0.5 | — | — | — | 0.8 V | — | — |
| 17-22-AS | 0.30 | — | R | — | 1.0 | 0.5 | — | — | — | — | 0.3 V | — | — |

*From a paper by J. B. Meierdirks, Jr. before AISI regional meeting, Philadelphia, Dec., 1952*

*This File Fact replaces one of the same title published in September 1953 (No. 260) which reported erroneous temperatures for "Intermediate Alloys" and "Other Jet Engine Alloys".*

# How Tempering Affects Corrosion

● DESPITE THE FACT that information on the effect of heat treatment on the corrosion resistance of 12% chromium steels has been available for a great many years, many users of these steels continue to employ heat treatments which seriously impair corrosion resistance and toughness.

The loss of corrosion resistance which hardened Type 410 steels undergo when tempered at 1000 to 1100 F, and their subsequent recovery of corrosion resistance when tempered at higher temperatures can be demonstrated readily by the use of a mild corroding agent such as water at 100 F, applied by a method of alternate wetting and drying.

After testing, the samples are rated by assigning letters indicating the relative amount of rust present. Data are shown in a table. These data show that the resistance to rusting in condensed water vapor at 100 F is very high when the hardened steels are tempered at 500 and 900 F. The resistance to rusting decreases when the steels are tempered above 900 F, the steels being lowest in resistance when tempered at 1000 F. In 0.08% and 0.09% carbon steels, tempering at 1400 F restores the resistance to the point where it becomes as good as that of hardened steels tempered below 900 F. In 0.10% and 0.11% carbon steels, tempering above 1100 F results only in partial recovery of resistance to rusting.

Many users of Type 410, among them prominent engine builders, specify a hardness of 32 to 38 Rockwell C which necessitates tempering in the range 1000 to 1100 F. Evidently the corroding conditions in such applications are sufficiently mild to permit the use of this heat treatment to develop the desired mechanical properties.

Although general rusting has not been encountered in such parts, another and even more serious corrosion phenomenon has been observed in Type 410 heat treated to 32 to 38 Rockwell C, namely, stress corrosion

**Steel Compositions—%**

| | |
|---|---|
| Steel A: | 0.109 C, 0.47 Mn, 0.41 Si, 0.13 Ni, 12.16 Cr, 0.01 Mo, 0.012 Al, 0.03 N |
| Steel B: | 0.108 C, 0.47 Mn, 0.32 Si, 0.46 Ni, 12.03 Cr, 0.27 Mo, 0.009 Al, 0.05 N |
| Steel C: | 0.097 C, 0.49 Mn, 0.22 Si, 0.44 Ni, 12.15 Cr, 0.39 Mo, 0.010 Al, 0.03 N |
| Steel D: | 0.08 C, 0.45 Mn, 0.39 Si, 0.13 Ni, 12.04 Cr, 0.47 Mo, 0.053 Al, 0.04 N |
| Steel E: | 0.082 C, 0.051 Mn, 0.27 Si, 0.56 Ni, 13.06 Cr, 0.18 Mo, 0.008 Al, 0.03 N |
| Steel F: | 0.092 C, 0.40 Mn, 0.27 Si, 0.14 Ni, 13.28 Cr, 0.59 Mo, 0.024 Al, 0.05 N |

**Effect of Tempering on the Resistance of Type 410**

| | Steel A | | Steel B | |
|---|---|---|---|---|
| | Hardness Rc | Water Vapor Rating | Hardness Rc | Water Vapor Rating |
| 1800 F ½ hr, oil | 43 | — | 42 | — |
| 1800 F ½ hr, oil; 500 F 1 hr, air | 40.5 | A, A | 39 | A, B |
| 1800 F ½ hr, oil; 900 F 1 hr, air | 42 | A, B | 41 | A, B |
| 1800 F ½ hr, oil; 1000 F 1 hr, air | 38 | D, D | 37 | D, D |
| 1800 F ½ hr, oil; 1100 F 1 hr, air | 24 | B, C | 25 | B, C |
| 1800 F ½ hr, oil; 1200 F 1 hr, air | 19.5 | C, C | 19 | A, C |
| 1800 F ½ hr, oil; 1400 F 1 hr, air | 11.5 | C, C | 11.5 | B, B |

*Rust Rating: A—Zero to very slight rust. B—Slight rust. C—Appreciable rust. D—Heavy rust.*

# Resistance of 12% Chromium Steel

by A. SIMON, Supervisor, Metallurgical Laboratory, Spaulding Works, Crucible Steel Co. of America

cracking. Laboratory investigations have indicated that Type 410 steels are most susceptible to stress corrosion cracking when tempered at 1000 F. This is the same tempering temperature which imparts poorest corrosion resistance to Type 410 in the alternate wetting and drying tests. Sometimes the hardnesses which require the use of tempering at 1000 to 1100 F are not warranted by the ultimate uses to which the parts are to be subjected, or by the methods of fabricating to be used in the manufacturing of parts.

Manufacturers who use 12% chromium steels should re-examine their specifications to determine whether they are getting the most out of their steels with respect to corrosion resistance. Among the questions to be asked are:

Is the hardness of 32-38 Rockwell C in my specification, which necessitates tempering in the range 1000 to 1100 F, absolutely necessary?

Can I tolerate a higher or lower hardness?

Can I use a lower tempering temperature and improve corrosion resistance even though the hardness is slightly higher?

Can I reach the same hardnes level by using a lower tempering temperature and specifying a steel of lower attainable hardness?

Have I taken into consideration the fact that 12% chromium steels are lowest in corrosion resistance when tempered at 1000 F?

## Testing Procedure

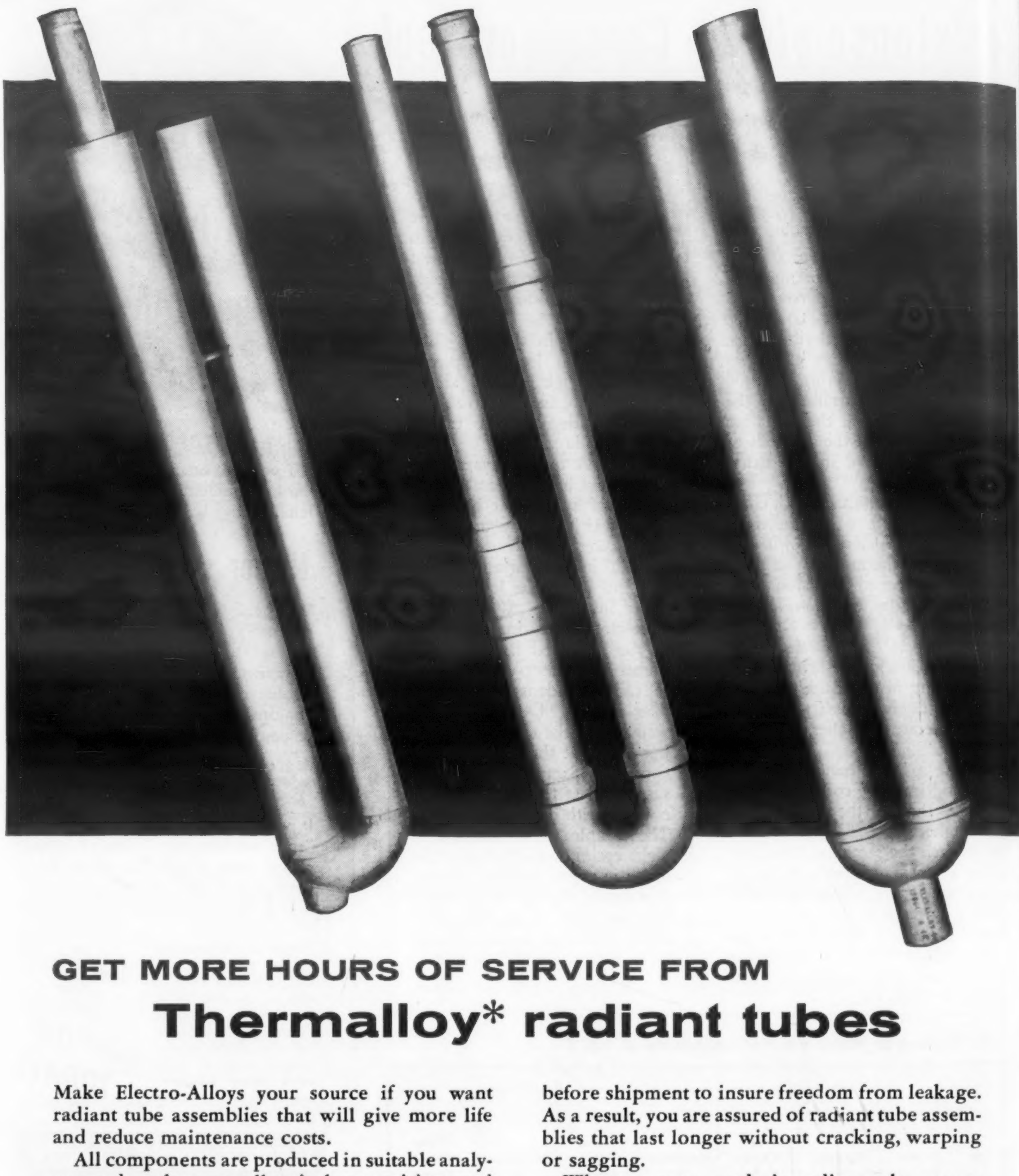
Strips from several commercial heats of Type 410 were hardened by an oil quench from 1800 F. Samples from each heat were then tempered for 2 hours at 500, 900, 1000, 1100, 1200 and 1400 F. The samples were ground to 1/8 in. thick by 1/2 in. wide by 3 in. long test pieces, drilled through one end, abraded and finished on 120-grit belts and degreased in carbon tetrachloride vapors.

Exposure to water vapor was carried out in an apparatus consisting of a large jar in which water was heated by an immersion heater and a vertical glass tube 36 in. long arranged with one end below the level of the water in the jar. Water vapor generated by heating the water in the jar filled the tube, the immersion heater was adjusted to cause condensation of approximately 24 in. over the water level, the temperature being 100 F at the point of condensation. Samples which were suspended at this point became covered with droplets of water. The samples were exposed to eight cycles consisting of eight hours in vapor followed by sixteen hours drying. After exposure for eight cycles, they were rated, refinished and re-exposed for a second eight cycle run.

**to Rusting in Water Vapor Condensate at 100 F**

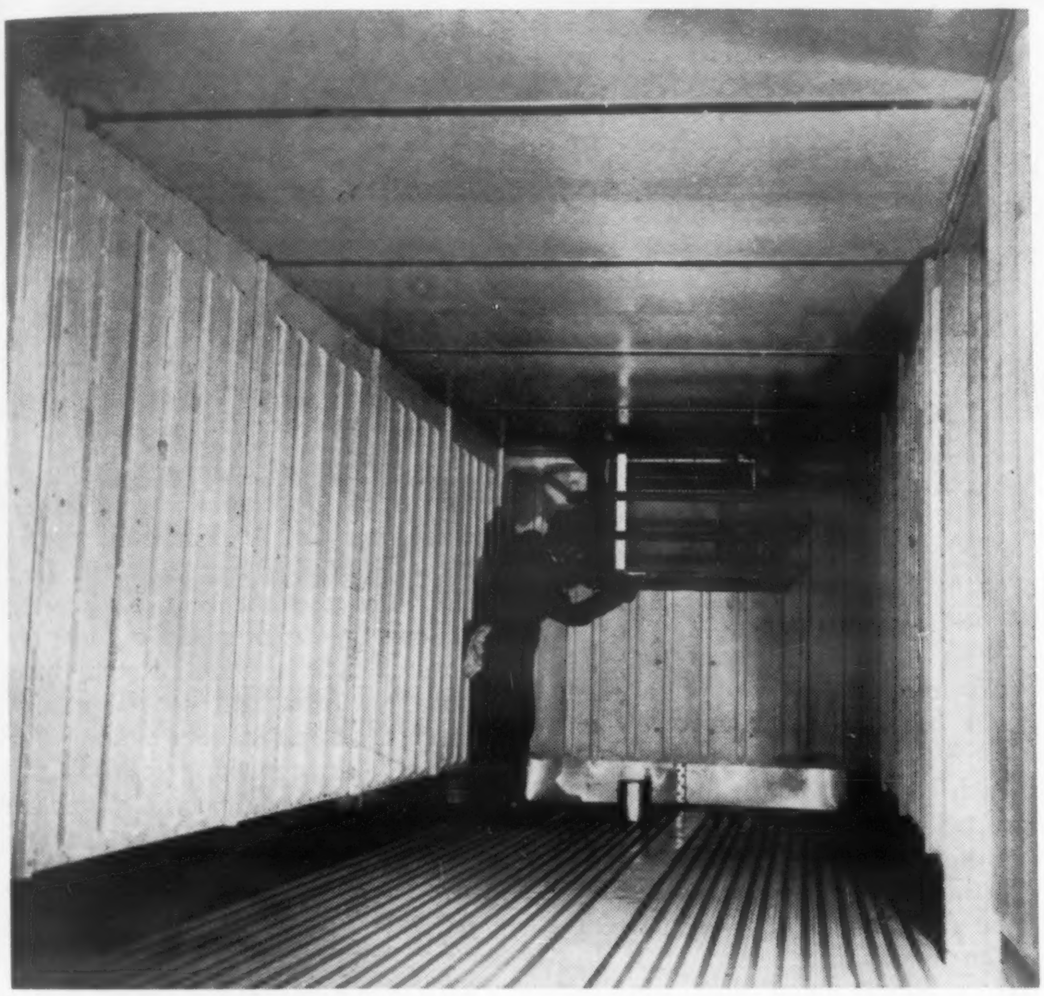
| Steel C | | Steel D | | Steel E | | Steel F | |
|---|---|---|---|---|---|---|---|
| Hardness Rc | Water Vapor Rating | Hardness Rc | Water Vapor Rating | Hardness Rc | Water Vapor Rating | Hardness Rc | Water Vapor Rating |
| 40 | — | 39 | — | 39 | — | 38.5 | — |
| 37.5 | A, B | 37 | A, B | 36 | A, A | 34 | A, A |
| 38 | A, A | 39 | A, A | 37.5 | A, B | 36 | A, B |
| 36 | D, D | 36.5 | D, D | 32 | C, D | 33.5 | C, D |
| 23 | C, D | 25 | A, C | 23.5 | B, B | 24.5 | A, C |
| 18 | C, C | 19 | B, C | 20 | A, C | 17.5 | A, B |
| 10 | B, B | 12 | A, B | 10.5 | A, B | 12.5 | A, B |

*NOTE: All samples were exposed to 8 cycles consisting of 8 hours wetting followed by drying overnight. The two ratings indicate results of first and second runs on same sample.*



# New Materials, Parts and Finishes

## ... and Related Equipment



Illustrating the expanding uses for reinforced plastic sheet is this view of a refrigerated truck trailer. The walls and roof are made of Naugatuck Chemical's reinforced Vibrin polyester resin.

*A Roundup of*

# Recent Reinforced Plastics

***This is the concluding half of the two-part roundup story on little-publicized resins developed recently for reinforced plastics.***

***The first part, which appeared last month, dealt with general purpose resins. This part covers resins for reinforced sheet and laminate, matched die molding and other resins which are in various stages of development. The latter are grouped under the heading of experimental, although some are now available for commercial evaluation.***

### Reinforced Sheet and Laminate Resins

One of the problems which has been difficult to overcome in developing resins for laminated sheeting for outdoor use is that of weatherability. A resin which has been developed particularly to overcome this problem is Selectron 5051A polyester, a product of *Pittsburgh Plate Glass Co.*, 1 Gateway Center, Pittsburgh. This is essentially a modification of that company's Selectron 5051 resin and displays the same characteristics except that it is light-stabilized for weathering applications. According to the company, weatherometer tests show no color change after exposure for 500 hr and only slight change after 1000 hr. It is furnished at 2400 to 3000 cps viscosity and may be thinned with additional monomer. It is said to gel and cure quickly with hydroperoxides commonly used in this application.

Vibrin 119 L S, developed by the *Naugatuck Chemical Div., U. S. Rubber Co.*, Naugatuck, Conn., is another polyester developed particularly for color-stable articles for outdoor use. It is said to have good resistance to sunlight discoloration, showing little or no change after 2000 hr exposure in a weatherometer. According to the company the material wets glass fibers readily and in the cured form has good translucency and physical properties.

### Self-Extinguishing

Though far from being the only criterion for fire resistance, the self-

# New Materials, Parts and Finishes continued

Compression molded radio cabinet of Plaskon's urea-formaldehyde plastics.

extinguishing characteristic of a resin is important in applications where flammability may be a hazard. DX-371 is a resin developed by *U. S. Industrial Chemicals Co., Div. National Distillers Products Corp.*, 390 Doremus Ave., Newark, N. J., and is self-extinguishing when tested according to ASTM D-635-52. It is also said to have a high degree of light stability, making it suitable for flame resistant corrugated outdoor sheeting. The company also recommends it for use in circuit breakers, switch boxes, and other electrical applications.

Polylite 8061 resin is designed for applications where transparency and light stability are not required. Developed by *Reichhold Chemicals, Inc.*, 630 Fifth Ave., New York 20, the cured resin is said to be heat-stable and to pass the Underwriters Lab heat stability test. The material can be handled in the same manner as conventional general purpose polyester resins. The addition of styrene to the material, however, tends to reduce its self-extinguishing characteristics.

### Air-Curing and Electrical

As was seen with the general purpose polyester resins, where the material is exposed to air some types of resin will not cure satisfactorily. These air-inhibited areas cure with a poor surface finish containing pin holes and craters. Polylite 8027 resin, also developed by *Reichhold Chemicals, Inc.*, is designed to overcome this difficulty in applications such as boat covering where a great deal of the surface is exposed to air during curing. Except for this characteristic, the material has the same properties as the general purpose Polylite 8007 resin.

For electrical applications a silicone resin has been developed by *Dow Corning Corp.*, Midland, Mich., which is said to retain high electrical properties after prolonged exposure to high temperatures. Called Dow Corning 2105 resin, it is said to provide fairly good flexural strength at room temperature, although it drops off rapidly at 500 F, indicating thermoplasticity. A high degree of thermal stability is indicated by a low moisture absorption and weight loss after prolonged exposure to temperatures of around 500 F.

### Matched Die Molding Resins

Designed to provide a fast cure while yielding a more craze resistant product, Selectron 5118 has been developed by *Pittsburgh Plate Glass Co.* particularly for matched die molding work. According to the company the material has been production molded in 30 sec at 250-260 F with good hot strength in the resultant part, and elimination of the residual odor often associated with polyester moldings.

DX-362 resin, a product of *U. S. Industrial Chemicals Co.*, was developed for molding and lay-up operations where color is not an important factor. The resin provides strengths on the order of those of general purpose resins, yet is said to be appreciably cheaper.

### Experimental

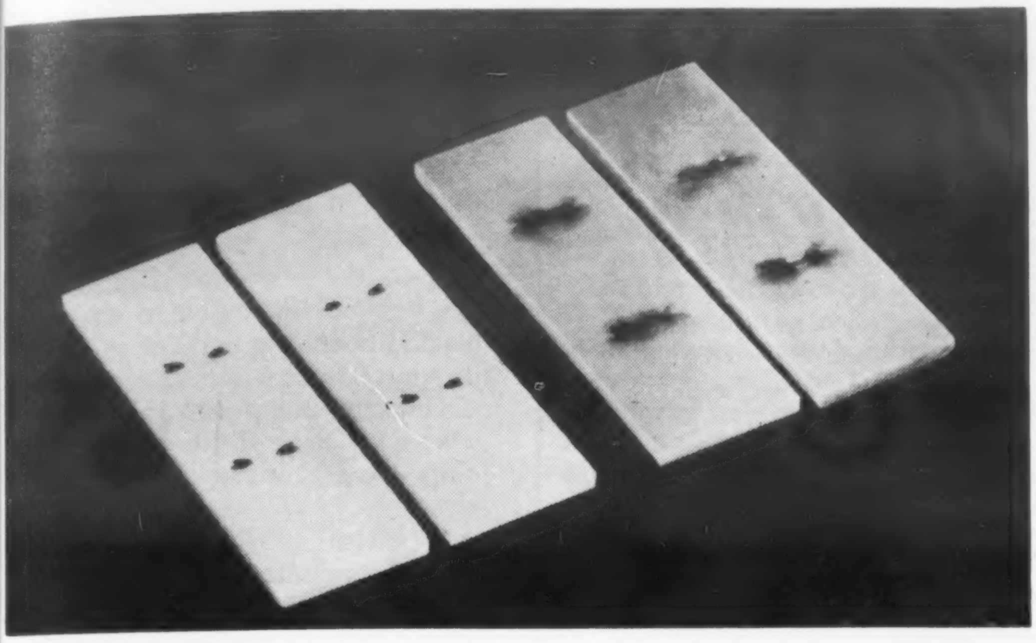
As was mentioned before, the resins grouped below are in varying stages of development. Some are in primary laboratory stages, others in service testing, and yet others are available for commercial evaluation. Selectron 5000, 514-68 developed by *Pittsburgh Plate Glass Co.*, is a 100% reactive, unplasticized, fire resistant resin. According to the company, castings made from the resin have been held at 400 F for 120 hr with a less than 20% loss of flexural strength. It is an all-purpose polyester resin, self-extinguishing, with a higher impact strength than other similar rigid resins.

Experimental Laminac Resin 4147, has been developed by *American Cyanamid Co.*, 30 Rockefeller Plaza, New York, to meet the need for a clear, fire resistant resin that does not yellow or discolor on outdoor exposure. It is a typical styrene based polyester resin and can be used in much the same manner as the typical non self-extinguishing resins. Other properties are comparable to standard intermediate resins such as Laminac 4115.

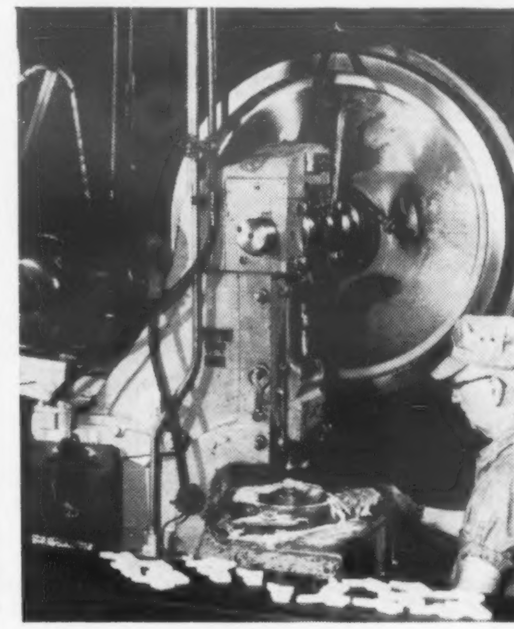
Experimental Laminac Resin PDL-7-719 has been developed by *American Cyanamid Co.* to meet the need for a material which will retain good dielectric properties at elevated temperatures. According to the company, a uniform dielectric constant, dissipation factor and dielectric loss factor is held through a temperature range of 75 to 300 F. It is a highly reactive polyester material and is recommended for impregnation of electrical components, particularly coils and capacitors.

Paraplex P-431 is a light-stabilized resin for outdoor use. Developed by *Resinous Products Div., Rohm and Haas Co.*, 222 W. Washington Sq., Philadelphia, the material is a modified version of Paraplex P-43 and is recommended for use in corrugated panels, skylights, and lighting fixtures

Laminac Resin 4231 is an unsaturated polyester alkyd resin which can be foamed in place. It is said to retain high dielectric and compressive strength properties at temperatures of 375 to 400 F. It is now being offered by *American Cyanamid Co.* for commercial evaluation.



Two samples of Phenolite at left are comparatively unaffected by same arcing test that burned across two NEMA Grade XX samples at right.



Workability is demonstrated by trimming ⅜-in. stock on shaving dies.

# New Plastic Laminate Has High Machinability, Electrical Properties

A new paper-base electrical grade plastic laminate employing polyester-modified melamine resin has been developed which is said to add improved machinability to the high electrical properties of the material.

Developed by *National Vulcanized Fibre Co.,* Wilmington, Del., the so-called Phenolite Grade Y-2401 has an arc resistance lying approximately midway between paper-base phenolics (NEMA Grade XXX) and paper-base melamines (NEMA Grade XX-M). With this increased arc resistance, dielectric strength, dissipation factor and moisture resistance, it is said to be comparable in machinability to the paper-base phenolics.

It can be drilled, sawed, turned and milled using standard tools rather than carboloy-tipped tools. And, since it is not brittle it can be rough-blanked closer to its final form, resulting in less machining time and and less waste of material. The laminates can be punched in thicknesses up to ⅛ in. in contrast with a maximum of 1/32 in. possible for comparable melamines used in electrical applications. Sections up to ⅜ in. can be shaped by shaving dies.

The material is intended for such electrical applications as transformers, television and radar insulation, circuit breakers, switch bases and supports for sliding contacts. It is available in 39 by 47-in. sheets in thickness of 1/32 to 1 in.

**Properties of Phenolite Grade Y-2401**

Specimens ⅛ in. thick, unless otherwise specified.
All tests except arc resistance conducted to ASTM and NEMA standards.

| | |
|---|---|
| Density | 1.35 |
| Flexural Strength, Psi | |
| Tested flatwise, As Received | |
| Lengthwise | 24,800 |
| Crosswise | 18,500 |
| Impact Strength, Ft lb per in. | |
| Tested edgewise, As Received | |
| Lengthwise | 0.48 |
| Crosswise | 0.40 |
| Water Absorption, % gain | |
| Condition E-1/105 followed by Condition D-24/23 | 0.62 |
| Rockwell Hardness (1/16 in. thick) | |
| Cold, "M" value | 108 |
| Dielectric Strength | |
| Parallel to laminations KV | |
| As Received | 63.0 |
| Condition D-48/50 | 17.3 |
| Perpendicular to lamination v/mil | |
| Short time test in oil, As Received | 585 |
| Dissipation Factor | |
| 1 Megacycle | |
| As Received | 0.0298 |
| Condition D-24/23 | 0.0315 |
| 60 cycles | |
| As Received | 0.017 |
| Condition D-24/23 | 0.037 |
| Dielectric Constant | |
| 1 Megacycle | |
| As Received | 4.21 |
| Condition D-24/23 | 4.32 |

| Arc Resistance, (No. of arcs) | *Y-2401* | *Grade XX* | *Grade XXX* |
|---|---|---|---|
| 15 KV, 30 ma; ⅜-in. gap; 113 arcs per min | 17 | 6 | 5 |

# New Materials, Parts and Finishes continued

**Properties of Teflon Filament Yarn**

| | |
|---|---|
| Specific gravity | 2.3 |
| Tensile strength*, Psi | 42,700 |
| Tenacity*, Gm/denier | 1.45 |
| Elongation at break*, % | 21.2 |
| Wet strength* | Equal to dry strength |
| Wet elongation*, % of straight | 75.3 |
| Dry, loop and knot strength* | 80.8% and 78% respectively of straight tenacity |
| Wet, loop and knot elongation* | 88.4% and 72.4% respectively of straight elongation |
| Modulus* | Low |
| Zero strength temperature, F | 590 |
| Gel temperature, F | 621 |
| Decomposition temperature, F | 750 |
| High temperature stability | Resists dimensional change; can be heat-set; good flex and abrasion; non-brittle |
| Possible useful temperature environment, F | 400–525 |
| Chemical stability | Only affected by fluorine gas and by chlorine trifluoride at high temperature and pressure, and by molten-alkali metals |
| Flammability | Non-flammable but melts with decomposition |
| Moisture absorption | Zero |
| Wettability | Most non-wettable fiber known |
| Adhesiveness | Fiber is slippery; few materials stick to it with any degree of adhesion |
| Coefficient of friction | Lowest of any fiber known. Boiled off yarn, dynamic 0.28, static 0.20 |
| Electrical properties | Excellent |
| Dyeability | Very poor |
| Color | Tan to brown; can be bleached white in strong oxidizing mineral acid |

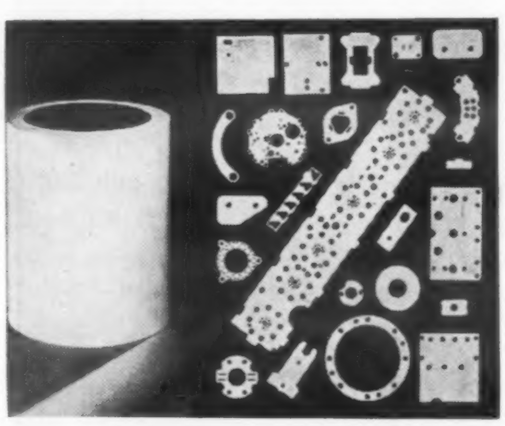
* *Instron Tests.*

## Fluorocarbon Fiber Produced

The DuPont fluorocarbon plastic, Teflon, is now being produced experimentally as a fiber by *E. I. du Pont de Nemours & Co., Inc.*, Wilmington 98, Del. Although no textile apparel uses are envisioned, it is expected that the fiber may find use in liquid-filtration fabrics, gas-filtration fabrics, packing for pump and valve shafts, gaskets for flanged piping and other joints, special conveyors and beltings, etc.

At present, 400 denier yarn with 60 filaments mounted on a 1-lb cone is being produced experimentally. Sales of the yarn for commercial evaluation are being handled by the industrial sales development group of DuPont's Textile Fibers Dept.

Properties of the new fiber are given at left.



***Sheet arrives in roll, can then be stamped into parts like those at right.***

## Plastic Laminate in Continuous Sheet

A paper-based polyester laminate is now available in continuous sheet form for use in the electronics, motor, electrical and radio and TV manufacturing field. Conolite EPNXXP is available in lengths up to 150 ft and 36 in. in width, and has a glossy white opaque finish allowing effective printing or embossing in black or colored lettering. Its thickness ranges from 0.0025 to 0.062 in.

Produced by *Continental Can Co.*, 100 E. 42nd St., New York 17, the material can be cut, drilled or cold punched automatically without chipping or fracturing, according to the company. Physical and electrical properties of the new laminate are said to conform to NEMA standards; these properties have also been accepted by the Underwriter's Laboratories.

## Two New Epoxy Resins

Two new epoxies, Bakelite C-8 resins BR-18774 and BR-18795 have been marketed by the *Bakelite Co.*, 260 Madison Ave., New York 16, to provide strong lightweight products with high chemical resistance and electrical properties. Four new hardeners have also been synthesized to produce the optimum properties of the materials which are expected to take their place in the rapidly expanding epoxy for draw dies, check fixtures, frames, patterns, tooling jigs, and other types of dies for automotive and aircraft production.

Delicate electronic assemblies that may be damaged by high temperatures can be cast at room temperature in a protective envelope made of the low shrinking resins. They are also said to be suitable for potting transistors, selenium rectifiers, capacitors, radio interference filters and other electronic components.

The resins are moneric, low molecular weight diepoxides. Thermosetting resins, they are rapid hardening with 100% reactive components when formulated with their complementary hardeners. The hardeners, BR-18793, BRR-18812, BR-18803, and BR-18807, are aliphatic polyamines synthesized to give the new epoxies a wide range of curing speed, viscosity and pot life.

*(Continued on page 146)*

# New Materials, Parts and Finishes

## New Glass Cloth Has High Strength, Lower Cost

A new type of glass cloth is said to possess higher strength and lower cost than cloth woven from typical glass yarn. These advantages are partly gained, according to the manufacturer, by taking the twist out of the yarn used in the weaving operation.

Developed by *Bigelow Fiber Glass Products*, 140 Madison Ave., New York 16, the material, called Rovcloth, is made up of bundles of individual parallel strands of glass fiber woven into cloth. In the conventional glass cloth the yarn is made up of individual strands twisted together, then woven into the finished product.

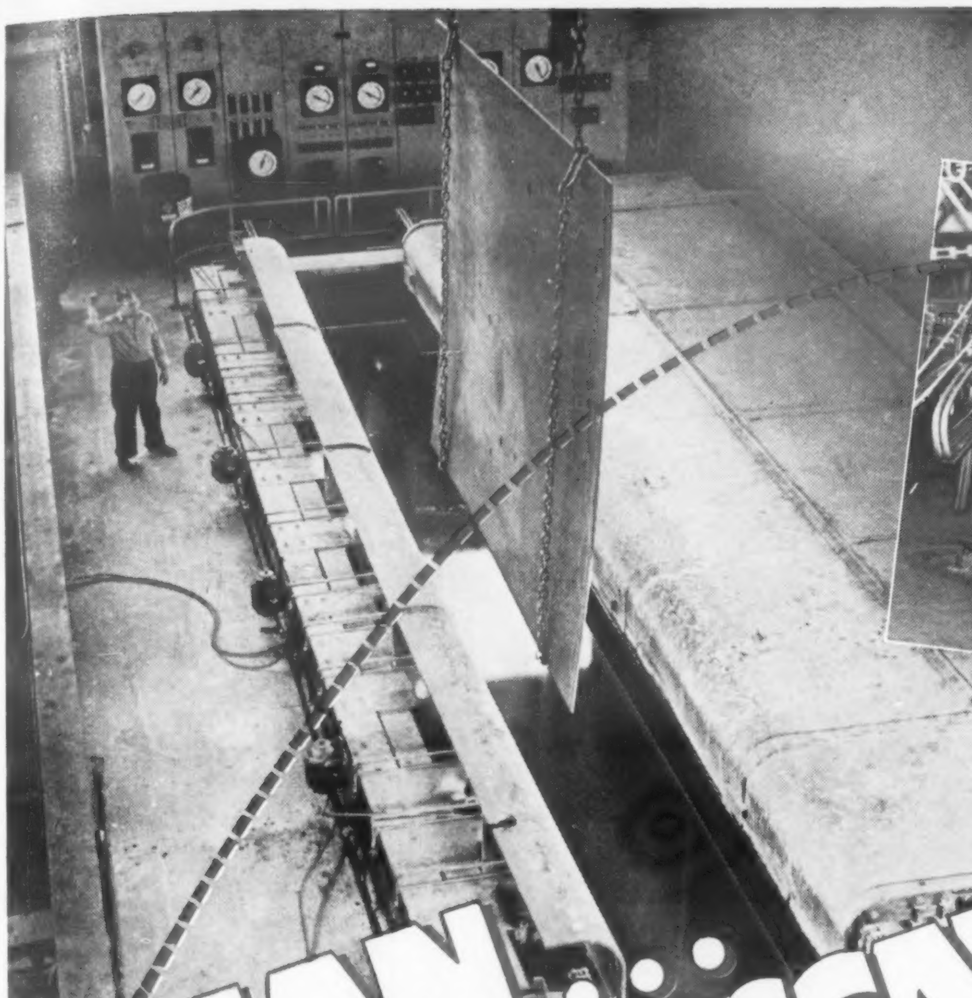
The strands of glass fiber in cloths must be sized, to lend abrasion resistance to the fiber during the weaving operation, and to insure complete impregnation of the material by the plastic resin used by the molder. The glass fiber manufacturers apply this sizing to the strands at the forming operation. If this sizing is of the Volan or Silane type, it imparts stiffness to the fibers, and in twisting the fibers into yarn they break.

To overcome this, strands that are twisted into yarns are sized with a starch type of sizing which will not stiffen the fiber, yet will act as a lubricant while weaving. This starch sizing, not being compatible with resins used in plastics manufacture, must be removed by heat cleaning, and replaced with a sizing such as Volan, Silane, etc. after the yarn is woven into cloth. Since the strands used in Rovcloth are not twisted, they can be sized originally with compatible sizes which do not require heat cleaning and subsequent refinishing.

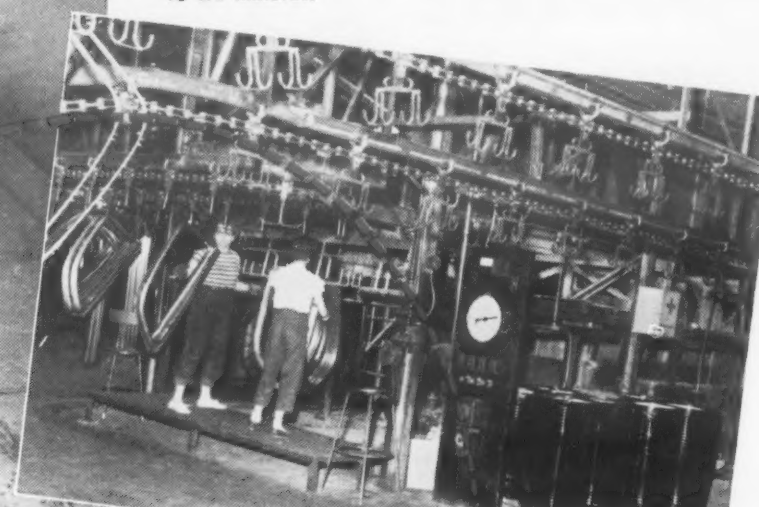
The fabric is available in sizes up to 144 in. wide, in varying types of constructions and thread counts. Additional advantages claimed for the material are:

1. Absence of twist gives increased strength, allows better wetting out of individual filaments.
2. Flat ribbon shape of roving gives better inter-laminate strength.
3. Increased bulk results in lower laminating cost.
4. No loss of strength due to heat-cleaning.

*(Continued on page 148)*



Stainless, carbon, alloy and high-speed tool steels and non-ferrous alloys descaled in from 15 seconds to 20 minutes.



Drawing compounds and paint stripped from metal stampings in 50 seconds.

# CLEAN . . . DESCALE . . . DESAND

## . . . faster, better at appreciably less cost

From removing metallic oxide scale from huge plates, coils or bars to desanding molds or cleaning residual materials from stampings, the Ajax Electric Salt Bath Furnace paves the way to appreciable savings in labor, floor space and time. What's more, the work is done far more efficiently than is possible with sand-blasting, acid pickling, electrolytic anodic cleaning or other methods.

The Ajax Salt Bath Furnace is adaptable to many metal and alloy types. Different metals and different metal shapes can be descaled simultaneously. The bath acts uniformly on all parts of the work including blind holes. The process reacts only on scale, sand or residual materials. The base metal is not affected and there is no hydrogen embrittlement. First cost of the equipment is low and so is upkeep. Pot and electrode life is measured in years and the bath can be regenerated indefinitely by the addition of low cost chemicals. Where desired, the entire process can be mechanized for highly efficient mass production.

Write today, giving details of your finishing problem. Let Ajax engineers prove these claims—at not the slightest obligation. Reprinted technical articles on cleaning, descaling and desanding are available on request.

Grease, drawing compounds, residual rubber, carbon black, plastics, paint and enamel removed in minutes with less labor.



Residual sand removed from these pump castings by 3-minute bath immersion at 700° F.

**AJAX ELECTRIC COMPANY**

WORLD'S LARGEST MANUFACTURER OF ELECTRIC HEAT TREATING FURNACES EXCLUSIVELY

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Associate Companies: Ajax Electric Furnace Corp.; Ajax Engineering Corp.; Ajax Electrothermic Corp.

AJAX Trademark

**ELECTRIC SALT BATH FURNACES**

For more information, turn to Reader Service Card, Circle No. 331

# New Materials, Parts and Finishes

## New Coatings Prevent Corrosion

Five new coatings have been developed by *Allied Research Products Inc.*, Baltimore, for corrosion protection of nonferrous metals. Two are suitable for zinc alloys and one each for silver, copper and aluminum. The new products are designed for application by a simple chemical dip, without electrolysis, special equipment or specially trained personnel.

### Zinc Alloys

Iridites #4-73 and #4-75 (Cast-Zinc-Brite) are said to provide bright-type decorative and protective finishes directly on Zamak #3 and Zamak #5 type alloy zinc die castings, respectivey. According to the company, the chemical polishing action of the Iridite solution imparts a luster to the metal surface, eliminating the need for mechanical polishing. In addition, the finishes can be used as preparations for electroplated finishes by chemically removing the protective film.

### Silver Plate

Iridite #18-P (Silver-Kote) is said to provide good tarnish resistance for industrial silver plate. The process is designed to provide a protective coating both in service and storage with minimum effect on electrical characteristics and solderability. The finish does not substantially change the appearance of the silver plate.

### Copper and Copper Alloys

Iridite #17-P (Cupreous - Kote) provides greater corrosion resistance and paint adherence for copper and copper alloy surfaces than can be obtained from Iridite #7. It is designed to perform on any copper or copper alloy without generating smuts and also to provide protection for soldered joints. The basic coating resembles the base metal in appearance and can be dyed yellow, red, orange or green for color identification.

### Aluminum

Iridite #14-2 (Al-Coat) is another addition to the Iridite line of aluminum finishes. Application of the coating can be controlled to produce a finish ranging in appearance from yellow-iridescent to a uniform deep brown. The deep brown finish is more




For more information, turn to Reader Service Card, Circle No. 466

## New Materials, Parts and Finishes

protective than other Iridite treatments for aluminum, according to the company. The coating can also be bleached to produce a clear appearance without damaging the protective qualities of the film.

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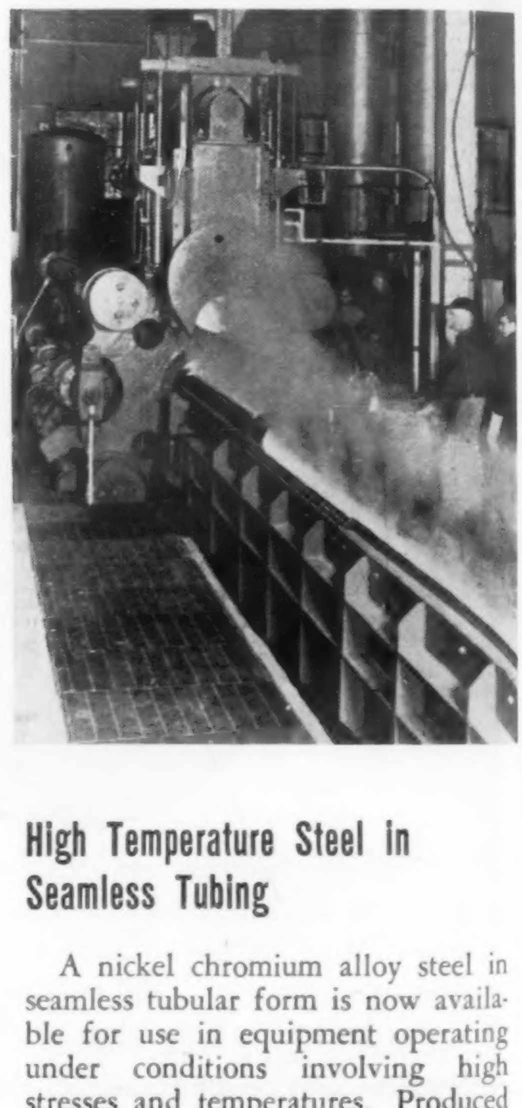


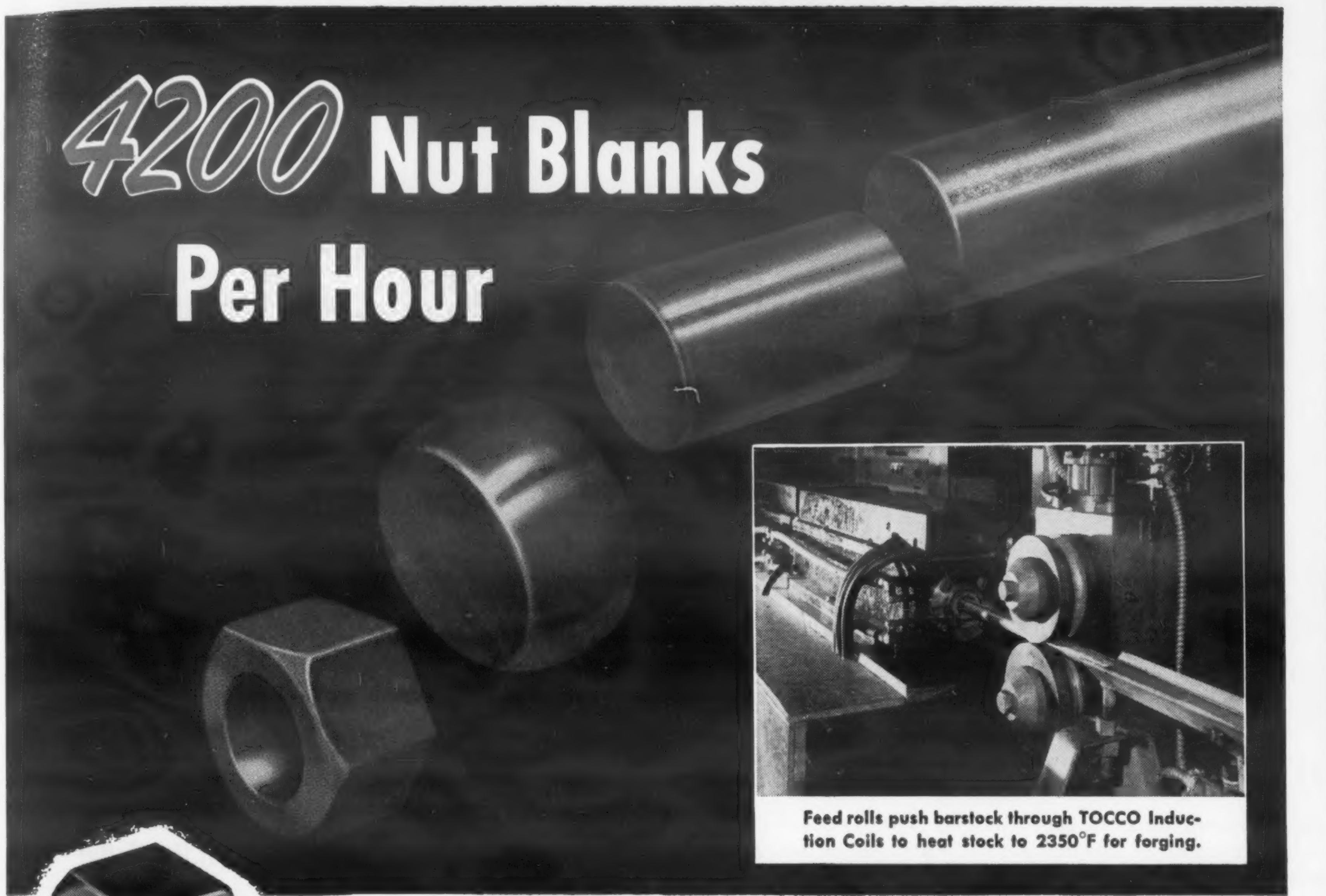
### High Temperature Steel in Seamless Tubing

A nickel chromium alloy steel in seamless tubular form is now available for use in equipment operating under conditions involving high stresses and temperatures. Produced by *Tubular Products Div., The Babcock & Wilcox Co.*, Beaver Falls, Pa., the tubing is being marketed under the name Croloy 19-9DL. The steel used is Universal Cyclops Uniloy 19-9DL.

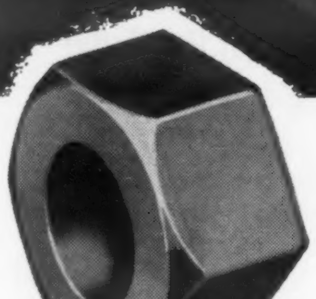
19-9DL is predominantly an austenitic stainless steel containg chromium, nickel, molybdenum, tungsten and small quantities of columbium, tantalum and titanium. It has good strength at temperatures up to 1200 F and is corrosion resistant with characteristics similar to high carbon, 18:8 stainless steel.

The tubing is being produced in limited sizes by the hot extrusion method, developed in France as the Ugine-Sejournet process.

*(Continued on page 152)*




Feed rolls push barstock through TOCCO Induction Coils to heat stock to 2350°F for forging.



# with TOCCO* Induction Heating

**FASTER PRODUCTION**—4200 nut blanks per hour—twice the output of a conventional hot punching machine—that's the result of Lamson & Sessions Company's new automatic production set up with TOCCO Induction Heating.

**OTHER ADVANTAGES**—TOCCO delivers exact temperatures (2350°F, plus or minus 25°) and delivers them so fast that scale has little time to form. Scale loss has been reduced to only about 1% for hot-rolled stock. TOCCO is clean and cool, fits right into the production line—no hauling to and from the heat-treat department—no unpleasant radiant heat to annoy workers.

**HERE'S HOW IT WORKS**—Steel bars up to 1½" diameter are fed through TOCCO Induction Coils. The first two coils, operating off a 300 kw, three kc TOCCO motor-generator set, preheat the rod. The third coil which operates from a TOCCO 250 kw 10 kc generator then boosts the rod to forging temperature. The hot rod then is fed to the special hot nut former (designed and built by NATIONAL MACHINERY CO.) which shears the rod to suitable lengths, forms the part and spits out the nut blank—ready for tapping.

In your search to find sound methods of increasing production, improving products and lowering costs, don't overlook TOCCO Induction Heating. If your products require heat treating, soldering, brazing or forging, it will pay you to investigate TOCCO for better, faster ways of producing them at lower unit costs.

**THE OHIO CRANKSHAFT COMPANY**

TOCCO

JUST PUSH A BUTTON

*Trade Mark Reg. U. S. Pat. Off.

*Mail Coupon Today*

**FREE BULLETIN**

**THE OHIO CRANKSHAFT CO.**
**Dept. T-7, Cleveland 1, Ohio**

Please send copy of "Typical Results of TOCCO Induction Heating for Forging."

Name__________
Position__________
Company__________
Address__________
City______ Zone____ State____

For more information, turn to Reader Service Card, Circle No. 367

# New Materials, Parts and Finishes

Data on properties of 19-9DL include the following:

| | |
|---|---|
| Charpy impact strength: | |
| Temperature | Ft Lb |
| 80 F | 46 |
| 1200 F | 56 |
| Stress to rupture | |
| Time, Hr | Stress, Psi |
| 10 | 50,000 |
| 100 | 44,000 |
| 1000 | 37,000 |
| 10,000 | 31,000 |
| Stress for secondary creep rates: | |
| Creep Rate, % per 1000 hr | Stress, Psi |
| 0.01 | 9800 |
| 0.10 | 19,500 |

## New Iron Powder Has Better Strength and Hardness

A new grade of reduced oxide type of iron powder has been developed by the *Plastics Metals Div., National Radiator Co.,* Johnstown, Pa. The powder is said to have good compacting properties and to result in parts with improved tensile and transverse strengths and hardness.

The material, called Plast-Iron Grade B-212, is said to be compatible with copper additions with respect to growth upon sintering, and to reduce the amount of copper needed.

The use of B-212 with 3% copper powder is said to provide tensile strengths about equal to those obtainable with other similar type powders with 10% copper. With 5% copper added, B-212 offers optimum transverse strengths, while tensile strength is said to be around 25% higher than similar 10% copper powders. More than 5% copper powder does not materially increase the tensile strength.

The addition of carbon to the B-212 and copper mixes appears to have some value when the copper is 3% or less; however, there is a loss of strength with higher percentages of copper, according to the company. Carbon does increase the hardness of these mixes and therefore may be justified when parts are to be hardened through heat treatment. However, the company warns against us-

◄ For more information, Circle No. 417

ing more than 3% carbon regardless of amount of copper additions.

Recommended sintering temperatures range from 1985 to 2050 F. Exceeding this upper limit may result in excessive warpage, etc.

In addition the material is said to offer the following advantages:

1. Plast-Iron 212 provides a tensile strength 2.4 times that obtained with similar types of powder.
2. The strength of transverse bars made from the material increases with sintering time and temperature. Transverse strengths are about double those obtained with other similar types of powder.

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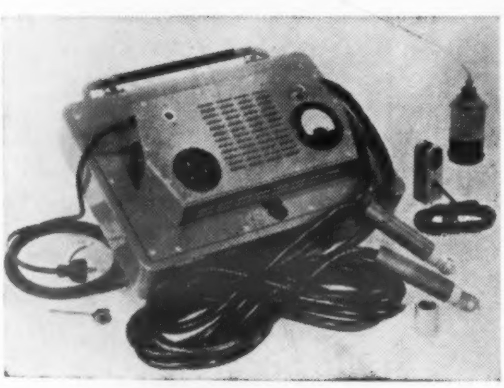


## Portable Unit Finds Surface Flaws

A magnetic-particle test unit weighing 45 lb and designed to locate surface defects in rough castings, bar stock, forgings and shop welds has been marketed by *North American Philips Co., Inc.*, Mt. Vernon, N.Y.

Called Portaflux the instrument works in this way: objects to be checked are magnetized either by passing a current directly through the metal or through a surrounding cable in the form of a coil; magnetic iron oxide or precipitated iron powder is distributed over the surface of the magnetized object and the alignment of the particles indicates the defect.

The unit has two heavy-duty, oil-resistant, insulated cables with renewable prods that carry currents up to 600 amp at a maximum voltage of 1.5 v. A metal coupler is provided for connecting the prods together

For more information, Circle No. 453 ➤

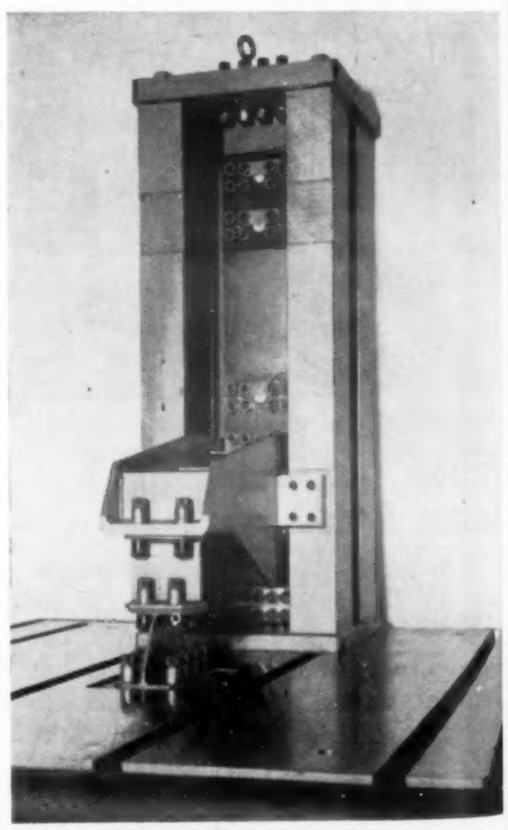
# New Materials, Parts and Finishes

when using the wrap-around coil method.

The control panel has an indicating type meter with a range of 0-600 amp. There is a 3-way selection switch for different ranges and a pilot lamp indicates when the high range is in use.

The instrument is useful for examinations at various stages of production, and during service for revision and repair. The light weight of the unit makes it useful for inspecting ship hulls, storage vessels, pipe lines and other large objects.

There is also an indicating device which shows the direction of the flux in the magnetized object and indicates the presence or absence of sufficient field strength.



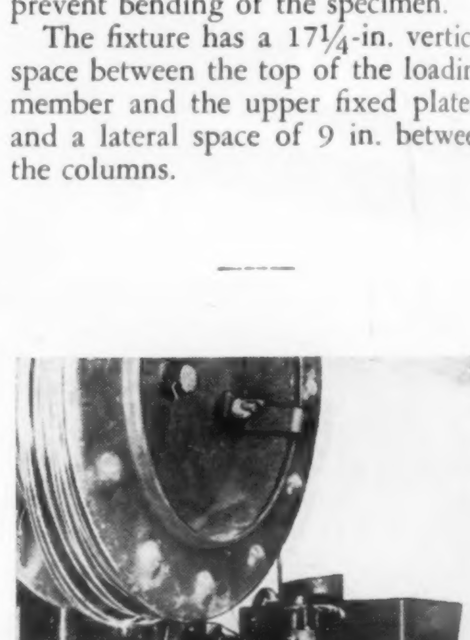
## Fixture Increases Capacity of Fatigue Tester

With the use of a newly developed fixture, fatigue tests can be carried out under loads up to 50,000 lb on a 10,000 lb capacity fatigue testing machine. The device, called the Sonntag Five-to-One multiplying fixture, is being produced by the *Baldwin-Lima-Hamilton Corp.*, Philadelphia, 42. The fixture is especially suited for testing flat materials, including metals

and plastics, as well as for joints that are riveted, welded or bonded. With the proper adapters, round specimens, chains, belts, and other parts can also be tested. Maximum deflection of specimens is ±0.050 in.

A simple lever principle is used in the fixture. A flex-plate acts as the fixed pivot of a 30-in. lever which is vibrated vertically by the oscillator of the fatigue machine. The specimen is loaded through another flex-plate 6 in. from the fixed pivot. The loading member is guided to move vertically by horizontal flex-plates which prevent bending of the specimen.

The fixture has a 17¼-in. vertical space between the top of the loading member and the upper fixed platen, and a lateral space of 9 in. between the columns.



### Oscillating Head Speeds Weld Build-Up

New automatic welding equipment which will produce beads up to 4 in. wide in a single pass has been developed by the *Lincoln Electric Co.*, Cleveland 17.

Called Spreadarc, the attachment mounts on a standard Lincolnweld automatic head and oscillates the head back and forth at right angles to the direction of travel. The amount of oscillation can be controlled to pro-

# New Materials, Parts and Finishes

duce a pad of weld metal in varying widths up to 4 in. According to the company it may be used to build up a layer of hardsurfacing metal or to build up with mild steel. Under proper conditions it may also be used to overcome poor fit-up conditions encountered in welding a joint.

The device is powered by its own variable speed electric motor which oscillates the entire welding head assembly by means of an eccentric. The width of the oscillation is controlled by adjustment of the eccentric and the number of oscillations per minute by a rheostat control of the motor speed.

Hardsurfacing with this equipment employs the hidden arc welding process and retains all the advantages of speed, uniformity and economy normally associated with the process when used for normal joint welding, according to the company. Typical applications are for scraper blades, tractor shoes, crusher rolls, shovel and dredge parts, hammers, crane ways, dipper teeth and bowl mills.

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## Cleaner Prepares Copper for Plating

A new compound specifically developed for electrocleaning copper and its alloys prior to plating has been marketed by *Oakite Products, Inc.*, 19 Rector St., New York.

The cleaner, Oakite Composition No. 191, is said to reduce tarnishing of work in the higher-temperature cleaning ranges, or where long treating cycles or prolonged transfer periods may occur. Advantages claimed by the company for the new material are: 1) long solution life, 2) broad current-density range, 3) wide temperature range (160 to 210 F), 4) low concentration of cleaner, 5) high rinsibility in both hot and cold water, 6) keeps tarnishing at a minimum.

The material is a free-flowing, fast-dissolving granular product whose solutions are colorless with little or no odor. Recommended concentrations start at 5 oz per gal, rising slightly as the solution ages to compensate for loss due to drag-out and carbonation of solution from carbon dioxide in the air.

*(Continued on page 160)*

## How a Fosbond cycle including Actidip can

# CUT YOUR PHOSPHATIZING COSTS AS MUCH AS 40%

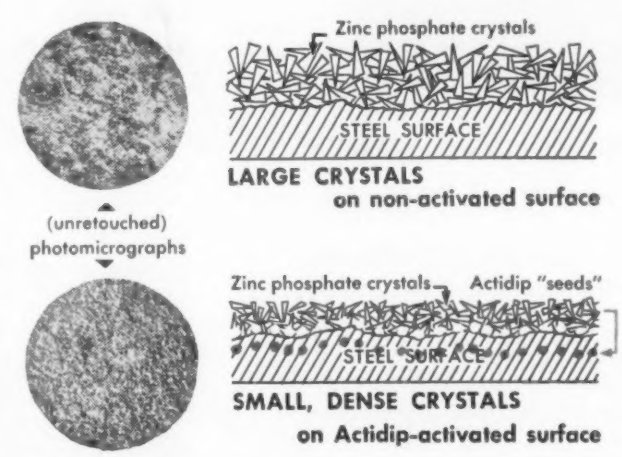
### If Your Company Now Applies Zinc Phosphate Paint-Bonding Coatings, This Is "Must" Reading For You!

A key component in Pennsalt's all-new Fosbond® Process is Actidip. Proper use of this extraordinary activating agent can cut consumption of zinc phosphating solution as much as 40% by reducing crystal size—and also assure a better, smoother organic finish. Because the phosphatizing bath is the major expense item in a paint-bond process, the reduced consumption possible with a Fosbond cycle including Actidip therefore can save thousands of dollars annually for any major user!

In many other ways, the Fosbond Process is just as noteworthy. It consists of a complete series of products and operations for *trouble-free* phosphatizing of metal prior to organic finishing. Fosbond locks finish to metal, and provides lifetime corrosion resistance. To get the process working smoothly in your plant *and to keep it that way*, Pennsalt offers the services of metal processing specialists.

**Like To See Test Panels?** Prove to yourself just how good Fosbond is! We'll send you test panels, or Fosbond chemicals with which you can make your own. Tell us, 1) type metal to be coated, 2) phosphate coating now used, 3) method of application, 4) organic finish used, 5) conditions finish must meet. Or, tell us about your phosphatizing operation, and we'll answer your questions as specifically as possible.

Better yet, say the word and we'll have one of our men tell you about Fosbond in person! Write: Customer Service Dept., Pennsylvania Salt Manufacturing Company, 528 Widener Bldg., Philadelphia 7, Pa.




**How Actidip Works**

Zinc phosphate crystals begin "growing" on steel from a starting point or nucleus. On a non-activated surface, growth is uncontrolled. Result: large crystals, high consumption of phosphatizing solution, irregular surface requiring more paint to cover.

Pennsalt Actidip "seeds" the surface with thousands of nuclei. Result: a controlled, more uniform, smaller crystal structure; a minimum of solution consumed to fully coat surface (up to 40% less); equal or better corrosion resistance with lighter coating due to more complete surface coverage; less paint to cover—or a smoother finish with same amount of paint.

The use of Actidip on certain steel surfaces which won't take an adherent phosphate coating has actually made it feasible to produce good coatings on these surfaces.

Actidip is applied by spray or immersion methods—by itself or compounded with a Pennsalt Cleaner. Actidip baths have long life and require no chemical control as the action of Actidip is a physical phenomenon and involves no chemical reaction. For best results, Actidip should be used in a Pennsalt-designed Fosbond cycle.

Guaranteed by Good Housekeeping

Fosbond has qualified for the Good Housekeeping Guaranty Seal, which is part of the colorful Fosbond emblem. Authorized Fosbond users may include this nationally-advertised emblem in their sales literature, product tags, etc., thus benefit from a proved merchandising device.

Finish locked on with FOSBOND Corrosion resistant undercoat

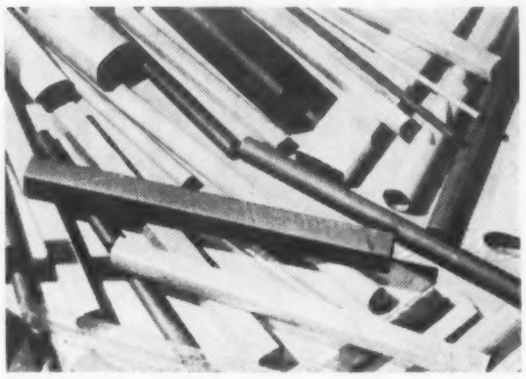
Actidip is a Pennsalt trade mark

A better start for your finish

Pennsalt Chemicals

For more information, turn to Reader Service Card, Circle No. 347

# New Materials, Parts and Finishes



## Low Cost Coil Forms Have High Dielectric Properties

To meet various dielectric requirements, materials such as kraft paper, fish paper, acetate or combinations (with phenol impregnation available) are used by *Precision Paper Tube Co.*, Dept. MMN, W. Charleston St., Chicago, in the production of coil forms.

Any requirements as to shape, size, length, inside diameter or outside diameter can be met and held within critical tolerances, according to the manufacturer. Sizes from fractions of 1 in. up to 9 in. are available without extra tooling charge.

By varying the materials used, a wide range of resistance to crushing, dimensional stability and tensile strength is available.

## Insert Aids Welding of Stainless Steel

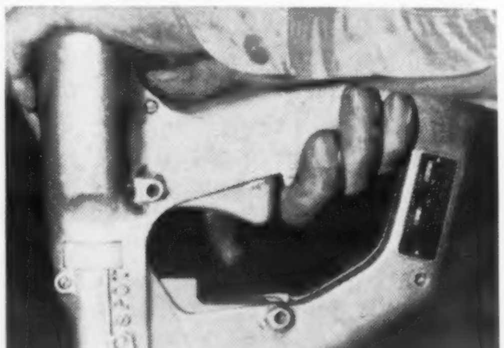
The EB Weld Insert is a welding process whereby a specially shaped insert is used to obtain smooth and uniform root passes on both sides of the weld even though the actual welding is done on one side only.

Marketed by the *Arcos Corp.*, 1500 S. 50th St., Philadelphia 43, the inserts should be used for welding stainless steels when accessibility is limited to one side, where smooth crevice-free weld contours are needed, and where high quality in the root pass is essential to the integrity of the completed weld.

The process, originally developed by the *Electric Boat Div., General Dynamics Corp.*, is carried out with an inert gas shielded tungsten arc torch. The weld groove is first pre-

pared and assembled with the weld insert in place. For optimum quality welds, the back side of the joint should be purged with helium or argon. When the arc is applied to the front side of the insert there is complete fusion during welding with equally uniform weld contours on the back, according to the company.

Use of the EB Weld Insert eliminates the need for a backing ring when welding pipe. This results in a reduced restriction to flow of fluids within the pipe, yet offers the proper control of the inside bead contours normally gained with the backing ring.



## Light-Weight Gun Aids Spot Welding

A light-weight (4 lb) spot welding gun using a 3/32-in. non-consumable, thoriated tungsten electrode and an inert-gas shield has been marketed by *Air Reduction Sales Co.*, 60 E. 42nd St., New York.

The Aircospot Gun is said to make instantaneous welds on sheets of stainless steel up to 3/32 in. thick, and mild and alloy steels up to 1/8 in. thick, by contact with one side of the work only. The gun eliminates the need for many jigs and fixtures.

The Aircospot unit consists of the hand gun, control panel and hose and cable assemblies. Requirements for use are a standard d.c. power source, and either a motor generator set or a rectifier type machine. The gun is water-cooled, and uses helium, argon or a mixture of the two.

# Contents Noted

**A digest of papers, articles, reports and books of current interest to those in the materials field.**

## *This Month:*

- ***Nine Die Casting Alloys***
- ***What's Ahead for German Plastics?***
- ***Electroplating on Titanium***
- ***Protecting Mild Steel from Heat***

## Sintered Refractory Alloys for Gas Turbine Blades

The operating efficiency of gas turbines is increased by increased operating temperatures. These higher temperatures have created the need for materials for the turbine blades which will maintain resistance to creep and general stability under these service conditions. The experimental work on this problem has been continuous, and the sintered refractory alloys, made up of metals and refractory materials, hold high promise of going far toward its solution.

In the January issue of *Metallurgia* (British) this year, A. Carter, of Hard Metal Tools, Ltd., discusses recent work done in England on these materials, with particular emphasis on the titanium carbide alloys. The metals generally used are cobalt, nickel, iron, chromium, silicon, beryllium, titanium, molybdenum, tungsten or niobium. The refractory constitutents are usually metallic carbides, nitrides, borides, silicides, or oxides. The physical and mechanical properties of the materials generally lie somewhere between those of the metal and those of the refractory ma-

**Properties of Principal Metal-Refractory Alloys**

| Alloy | Composition, % | Hardness, V.P.N. | Transverse Rupture | | Stress-Rupture Properties | | |
|---|---|---|---|---|---|---|---|
| | | | Temp. | Strength, ×1000 Psi | Temp., F | 100 hr, ×1000 Psi | 1000 hr, ×1000 Psi |
| Turbide R34 | Medium Nickel $TiC$-$Cr_3C_2$ | 800 | R.T.[2] | 150 | 1472<br>1796 | 32.3<br>11 | 19.3<br>5.4 |
| Turbide R45 | High Nickel $TiC$-$Cr_3C_2$ | 670 | R.T. | 180 | 1382<br>1796 | 31.5<br>9.5 | 23<br>4.7 |
| WZ Ib | 60 TiC, 32 Ni, 8 Cr | 1010 | R.T. | 190–210 | 1472<br>1796 | 46<br>14.2 | 37<br>7.9 |
| WZ Ic | 50 TiC, 40 Ni, 10 Cr | 830 | R.T. | 210–240 | 1796 | 14 | 8.2 |
| WZ 2 | 60 TiC, 28 Co, 12 Cr | 1160 | R.T. | 156–177 | 1796 | 10.3 | 7.8 |
| WZ 12a | 75 TiC, 15 Ni, 5 Co, 5 Cr | 1220 | R.T. | 148–163 | 1796 | 9.5 | — |
| K138A | 80 TiC-TaC-NbC, 20 Co | 89.5 Ra[1]<br>1400 | R.T.<br>1796 F | 150<br>100 | 1796 | 11.5 | — |
| K151A | 80 TiC-TaC-NbC, 20 Ni | 89 Ra<br>1350 | R.T. | 150 | 1796 | 11.5 | 7.4 |
| K152B | 70 TiC-TaC-NbC, 30 Ni | 85 Ra<br>1000 | R.T. | 180<br>190 | 1796 | 5 | — |
| ZrC-Nb | 87.5ZrC, 12.5 Nb | — | 1994 F<br>2397 F | 25.2<br>15.9 | — | — | — |
| $B_4C$-Fe | 64 $B_4C$, 36 Fe | — | 1994 F<br>2594 F | 25.2<br>23.4 | — | — | — |
| CrB-Ni | 85 CrB, 15 Ni | 87.4 Ra | R.T. | 123 | 1498<br>1600 | 4.6<br>2.6 | 3.5<br>1.7 |
| Metamic Lt-1 | 70 Cr, 30 $Al_2O_3$ | 35 Rc | — | — | — | — | — |
| $Al_2O_3$-Cr | 70 $Al_2O_3$, 30 Cr | 1100–<br>1200 | — | — | 1796<br>2196 | 16.2<br>12 | — |
| Nimonic 90 | Forged Ni-Co-Cr<br>Heat-treated alloy | 250–<br>350 | — | — | 1498 | 28 | 18 |
| Nimonic 95 | Forged Ni-Co-Cr<br>Heat-treated alloy | — | — | — | 1498<br>1697 | 31.4<br>11.2 | — |

*NOTES:*
*[1] Ra signifies Rockwell "A" Scale and Rc Rockwell "C" Scale.*
*[2] R.T. signifies Room Temperature.*

terial, since both are usually present in continuous skeletons. The properties are based on the high resistance to creep and general high-temperature stability of the refractory phase, combined with the good thermal shock resistance, good thermal and electrical conductivities, and ductile character of the metal bonding phase.

At present, the author points out, the most important of the materials for gas turbine use are the titanium carbide alloys. They have high hardness and strength, good thermal conductivity, low thermal expansion and general structural stability. And, since alloys of titanium carbide and nickel, cobalt or iron can be sintered with a liquid phase in equilibrium with the carbide skeleton, sound strong parts can be produced having high creep strength, high resistance to thermal shock, and, after suitable alloying, good oxidation resistance.

More is known about these alloys, according to the author, than about any other type of metal-refractory alloy. However, even these alloys are not yet ready to replace conventional forged blading alloys in gas turbine rotors, and the engine tests carried out to date represent only the first stage in the introduction of the new high-temperature materials.

Some of the corollary problems encountered in the development of these materials in this use are methods of attaching the blades to the turbine disks, and the simplification of blade shape in order to reduce the diamond machining required after sintering.

Titanium carbide-base alloys can probably be used at higher temperatures than Nimonic blades, but this increase is limited as the alloys have very little tensile strength at temperatures of 2370 F and up, owing to the formation of the liquid phase. For temperatures in excess of this, possibly the chromium-alumina cermets will be used. The accompanying table gives the composition and properties of the principal metal-refractory alloys, showing those of two Nimonic alloys for purposes of comparison.

## Mechanical Properties of Nine Aluminum Die-Casting Alloys

With the introduction of the cold chamber die-casting process, along with the development of stronger aluminum alloys suitable to this process, the use of aluminum die-casting for load bearing applications has grown considerably. In a paper given before the American Foundrymen's Society Annual Meeting this year, C. O. Smith, Aluminum Company of America, described typical mechanical properties of nine of the more common aluminum alloys used in this process. Particular attention was given to SC84 B alloy (Alcoa 380) since it is generally considered to be

**Typical Mechanical Properties of Aluminum Die-Casting Alloys (1)**

| Alloy Designation | | Tensile Strength psi | Tensile Yield Strength (2) psi | Elongation in 2 in. % | Compressive Yield Strength (2) psi | Shearing Strength psi | Endurance Limit (3) psi |
|---|---|---|---|---|---|---|---|
| Alcoa | ASTM | | | | | | |
| 13 | S12B | 39,000 | 21,000 | 2.0 | 15,000 | 25,000 | 19,000 |
| 43 | S5C | 30,000 | 16,000 | 9.0 | 13,000 | 19,000 | 17,000 |
| 85 | SC54B | 40,000 | 24,000 | 3.0 | 19,000 | 26,000 | 23,000 |
| 218 | G8A | 45,000 | 27,000 | 8.0 | 23,000 | 28,000 | 23,000 |
| 360 | SG100B | 44,000 | 27,000 | 3.0 | 20,000 | 28,000 | 20,000 |
| A360 | SG100A | 41,000 | 23,000 | 5.0 | 18,000 | 26,000 | 18,000 |
| 380 | SC84B | 43,000 | 26,000 | 2.0 | 21,000 | 28,000 | 20,000 |
| A380 | SC84A | 42,000 | 21,000 | 3.0 | 17,000 | 27,000 | 20,000 |
| 384 | — | 46,000 | 27,000 | 1.0 | 21,000 | 29,000 | 21,000 |

*NOTE:*
*(1) Tensile properties are average values obtained from ASTM standard round die-cast test specimens, ¼ in. in dia, produced in a cold chamber (high-pressure) die-casting machine.*
*(2) Offset equals 0.2 per cent.*
*(3) Based on 500,000,000 cycles of completely reversed stress using R. R. Moore type machine and specimen*

the best general purpose alloy, and the effects of elevated temperatures on the alloys were emphasized.

No appreciable reduction in the properties of 380 alloy occurs until a temperature of about 250 F or over is reached. With the increase in temperature above this range, the tensile and yield strengths decrease sharply after a ½-hr exposure. An improvement in properties due to artificial aging occurs in the alloy when heated to 212 F for extended periods of time; however, this is not noticeable in the alloy at higher temperatures. It probably occurs to some extent, but only for very limited periods of time, after which the properties decrease. This behavior is found to occur in varying degrees in all the aluminum die-casting alloys.

### Notch and Surface Removal Effects

The notch endurance limit of Alloy 380 rotating beam specimens was found to be about 35 to 40% of that obtained with smooth specimens. However, the author points out that such a reduction of endurance limit from a notch is not surprising since the stress is calculated from the simple elastic beam formula in which the minimum diameter of the specimen is used. What did seem surprising was the fact that there seemed to be no appreciable difference in endurance limits for those specimens with machined notches as opposed to cast notches, nor between specimens with notches of 0.001-in. root radii and notches with 1/32-in. root radii.

## Future of Plastics in Germany

Since 1951, Western Germany has been second only to the United States in the production of plastics in the Western Hemisphere. In that year they inched ahead of Great Britain and last year held a commanding lead of 264,000 tons as compared with 214,500 tons production in Great Britain. These facts are pointed out in a brief article on the German plastics industry by Gerhard Matulat in the first issue of *Chemische Industrie* (German) this year.

At present, West Germany exports approximately 14% of their total plastics production. This figure is not expected to rise as long as Germany's competitors in the rest of the Western world maintain high tariff walls

## Contents Noted continued

and are aided by government subsidization. Therefore, the immediate future of the industry in that country lies predominantly in increased home consumption, and in Germany, as elsewhere, the responsibility for bringing this about lies 1) with the producers in increasing the quality and reducing the price of their materials, and 2) with the processors in selling the public on the merits of plastics by manufacturing well-engineered, attractive goods. The designer must be made more aware of the advantages peculiar to plastics, and the man in the street must come to know as much about these materials as he does about wood, iron, glass and rubber.

The author points out that a conservative estimate of the capital investment needs of the West German plastics industry up to the end of 1955 is 150 million German marks (35.7 million dollars). At present there is no operating capital market capable of supplying the long-term credits needed for investment on this scale. And finally Mr. Matulat emphasizes the uncertainty of the industry due to its dependency on the political future of Europe. The unification of Germany would add a potential market of 18 million people who are now in East Germany. In addition, if the chemical and plastics capacities of East Germany were integrated with those of West Germany, the German plastics economy would be greatly improved.

## How to Electroplate Titanium

Electroplating on titanium may be necessary for decorative purposes, for improved resistance to high-temperature gases, for improved mechanical properties of the surface, or to aid in the joining of titanium parts. Since titanium is a highly active metal and forms an impervious and tightly adherent oxide film on its surface, it has been extremely difficult to obtain a good electroplate on the metal.

In a paper printed in the Nov., 1953 issue of the *Journal of the Electrochemical Society,* W. H. Colner, M. Feinleib, and J. N. Reding detail a method for gaining a highly adherent electroplate on the metal.

By anodically etching the surface of the material in a solution based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Halliburton Oil Well Cementing Company, Duncan, Oklahoma, selected hot rolled MAX-EL 3½ bar stock for the valve shown. It's an important part of their 5⅞″ tester, used to sample fluids or gases during drilling operations, sometimes 15,000 to 20,000 feet below the surface.

The valve is machined in the annealed condition and then heat-treated. Even though it varies considerably in thickness, no distortion problems are encountered in this MAX-EL part.

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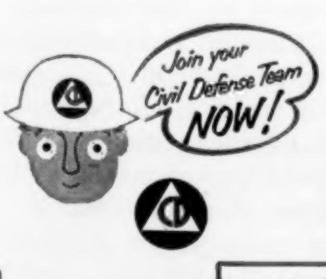


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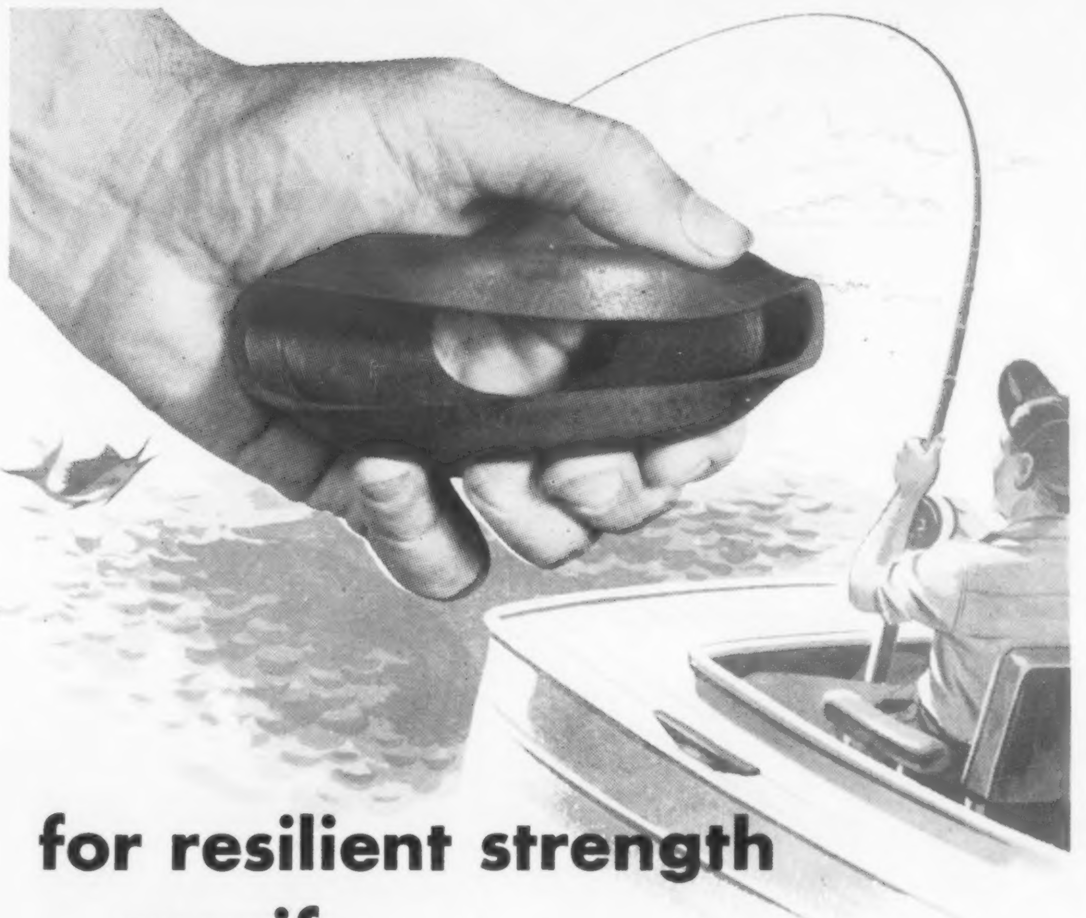



# Contents Noted | continued

on HF and ethylene glycol before plating, good copper electroplates up to 0.005 in. thick were obtained. The authors point out that the bond is a mechanical one due to the interlocking of the plate with the roughened surface of the titanium. Under controlled conditions of temperature and current density, the plated metal appears to throw well into the cavities created by the etching action.

## Protection of Mild Steel at High Temperatures

Mild steel can be used for many purposes at elevated temperatures if it is protected from oxidation. This can be done in several ways; the surface of the steel can be impregnated with metals with intrinsically higher resistance to oxidation, or various types of vitreous enamels can be applied.

In the April, 1954 issue of *Metallurgia* (British) A. H. Sully, E. A. Brandes, and R. H. Brown, discuss the results of comparative tests at the Fulmer Research Institute on this problem. Temperatures used ranged upwards of 1290 F. The results of their tests indicated that in terms of absolute resistance to oxidation, impregnation with chromium is the most effective treatment. Although oxidation-time curves for aluminum-protected specimens show larger weight increases than those for the chromium-protected specimens, the degree of protection afforded by the aluminum seems to be adequate for most applications at around 1290 F. At higher temperatures, the authors indicate that the chromium would probably show a greater superiority over the aluminum, although their present work did not extend into this area.

Certain of the enamel coatings tested showed a surprising degree of protection at 1290 F. The most successful was a U. S. National Bureau of Standards coating, A.417, which at a thickness of 0.002 in. withstood oxidation for 1000 hr at 1290 F. These coatings were applied by spraying an aqueous slip, and firing at temperatures of around 1650 to 1830 F for 3 to 5 min. However, the authors believe that 1290 F is the approximate limiting temperature for this type of coating for long periods of service.

# Contents Noted

## Books

**Engineering Alloys.** *Norman E. Woldman. American Society for Metals, Cleveland, Ohio, 1954. Cloth, 6 by 9 in. 1034 pages. Price $15.00*

The third edition of this well-known compilation on engineering alloys follows the system used previously. During the seven years which have passed since the publication of the second edition, data on more than 7000 new proprietary alloys have been accumulated. These materials are incorporated in this edition.

The section on uses and applications which was published in the previous editions has been deleted. The author states that the possible applications of specific alloys have become so numerous that this section has no practical value.

To the engineer and metallurgist who must answer such questions as "What is the composition of—alloy" or "Who makes—alloy", this book is invaluable.

**Metals and How to Weld Them.** *T. B. Jefferson and Gorham Woods. James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio, 1954. Cloth, 6 by 9 in. 322 pages. Price $2.00.*

This is a combination text and reference book which aims to supply a working knowledge of welding to all users. It is organized to explain in logical steps, the structures and properties of metals and welding procedures for them.

The first 6 chapers are devoted to an elementary discussion of metals and their properties. This section is followed by chapters on welding and heat treatment in general. Ten chapters are then devoted to procedures for the welding of specific materials principally iron and steels, although a chapter on welding the non-ferrous metals is included. The final section is devoted to information on making good welds, trouble shooting, cost estimating, and an explanation of welding terms.

The book should prove useful to the welding operator, supervisor, instructor and student for class or home study use.

**Titanium and Titanium Alloys.** *John L. Everhart. Reinhold Publishing Corp., New York 36, N.Y., 1954. Cloth, 4½ by 6½ in. 184 pp. Price $3.00.*

The first in a new series of Reinhold Pilot Books, this work is in-

## Contents Noted | Books continued

tended for the engineer or designer interested in the possibilities of applying titanium in the solution of his problems. The author presents here a selective review of the work covered in scientific and technical journals and business publications, supplemented with information obtained from the producers of the commercial materials. Dealing with the engineering and fabricating properties of titanium, the book includes chapters on High Purity Titanium (covered very briefly), Properties of Commercial Titanium, Properties of Commercial Titanium Alloys, Heat Treatment, Forming and Fabricating, Joining, Machining and Grinding, and Cleaning and Finishing.

Written in easy-to-understand terms, this book clearly indicates the present state of knowledge of titanium technology and points to some of the directions in which progress can be expected.

**Graphics in Engineering and Science.** *A. S. Levens. John Wiley & Sons, Inc., New York 16, N.Y., 1954. Cloth, 7 by 10 in. 696 pp. Price $7.00.*

This work has two principal objectives: to help the reader obtain greater appreciation of this important mode of expression, and to enable him to use it in analyzing and solving problems in science and engineering. Part I of the book, dealing with orthogonal projection, applies basic concepts to a variety of problems and emphasizes the analysis necessary for their solution. Part II deals with recognized standards, the importance of technique and the development of freehand drawing as a means towards intelligible expression. In Part III, the author is concerned with graphical solutions and computations.

**Machinery's Handbook, Fifteenth Edition.** *Erik Oberg and Franklin D. Jones. The Industrial Press, New York 13, N.Y., 1954. Cloth, 5 by 8 in. 1911 pp. Price $9.00; add 92 cents for postage to Canada and overseas.*

Here is a reference book on machine design and shop practice for the mechanical engineer, draftsman, toolmaker, and machinist. It makes available in ready-to-use form the new and hard-to-get as well as the established standard data and information needed by the mechanical industries. This latest edition combines all of the valuable features of earlier editions with the most recent and use-

# Contents Noted | Books continued

ful data obtainable. It contains 1911 pages of mechanical tables, rules, formulae and general data.

**The Properties of Glass.** *ACS Monograph #124. George W. Morey, Reinhold Publishing Corp., New York 36, N.Y., 1954. Cloth, 6 by 9 in. 591 pp. Price $16.50.*

This up-to-date revision will be welcomed particularly by the glass engineer and technologist who desires a critical review of the entire field of glass research, the scientist who must apply data on glass to other fields of research, and the general reader who wants information on glass in general. This new edition is larger than its predecessor and contains a greater number of tables and illustrations. Completely new sections on non-silicate glasses and the effects of radiation on glass have been added. Literature references through the middle of 1953 are included.

**Handbook of Industrial Electroplating.** *E. A. Ollard and E. B. Smith. Iliffe and Sons, Ltd., London, S.E. 1, England, 1954. Cloth, 6 by 9 in. 364 pp.*

The Handbook is intended for those whose duty it is to design, erect, maintain or operate electrodeposition plants, and also for laboratory workers who have to deal with the testing and maintenance of plating solutions. This second edition contains new sections dealing with water and drainage, the purification of solutions, safety precautions and ventilation in plating shops. Many new formulae for solutions as well as details of the latest advances in testing deposits are given, while a number of additional tables for references have been provided.

**1953 Supplements to Book of ASTM Standards.** *American Society for Testing Materials, Philadelphia 3, Penna., 1954. Price, $3.50 per part—or $24.50 for complete set of seven parts.*

The 1953 Supplements, issued in seven parts, give in their latest form 325 specifications, tests and definitions which were either issued for the first time in 1953 or revised since their appearance in the 1952 Book. *Part 1. Ferrous Metals.* 380 pages. This includes 62 standards covering steel piping materials (welded and seamless, high-temperature service, stainless, etc.), steel tubes (heat exchanger and condenser, still tubes for

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## Contents Noted | Books continued

refinery service, seamless and welded for general service, etc.), structural and plate, bolting materials, forgings, rails and accessories, concrete reinforcement steel, metallic coated steel products, welding electrodes and rods, cast iron, magnetic materials, and the Tentative Methods and Definitions for Mechanical Testing of Steel Products (A 370-53 T). *Part 2. Non-Ferrous Metals.* 288 pages. Included here are 49 standards covering metallic electrical conductors, copper and copper-base alloys, aluminum and aluminum-base alloys, magnesium and magnesium-base alloys, solder metal, die cast metals and alloys, electrical resistance and related alloys, metal powder products, electrodeposited metallic coatings, general testing methods. *Part 3. Cement, Concrete, Ceramics, Thermal Insulation, Road Materials, Water-proofing, Soils.* 400 pages. This part contains 62 standards. *Part 4. Paint, Naval Stores, Wood, Fire Tests, Sandwich Constructions, Building Constructions, Wax Polishes. 174 pages.* Included here are 30 standards covering pigments (white and nonhiding), drying oils and thinners, shellac, varnish, lacquer, and related products, traffic paint (roundness of glass spheres), general paint tests, naval stores, wood and wood preservatives, structural sandwich constructions, wax polishes, fire tests, specifications for ASTM Thermometers, general testing methods, *Part 5. Fuels, Petroleum, Aromatic Hydrocarbons, Engine Anti-Freezes.* 348 pages, 47 standards. *Part 6. Rubber Plastics, Electrical Insulation.* 208 pages, 28 standards. *Part 7. Textiles, Soap, Water, Paper, Adhesives, Shipping Containers.* 308 pages, 47 standards.

**Facts About Stampings.** *Pressed Metal Institute, Cleveland 20, Ohio, 1954. Paper, 5-1/2 by 8 1/2 in. 32 pp Price 50 cents.*

This book is offered as an aid to those who are faced with problems in the designing and redesigning of parts for metal stamping products. Included in the subjects covered are: Holes, Flanges, Flanges and Radii, Layout, Notches and Slots, Gage Inspection, Tolerances, Steel Gages, Dimensions, Checklist for Prints, Press Section, Definitions, and suggested Terms and Conditions of Sale for the Industry.

**Chemical Engineering in Practice.** *Edited by James I. Harper. Reinhold Publishing Corp., New York 36,*

*N.Y., 1954. Cloth, 5 by 8 in. 140 pp. Price $3.00.*

This book is based on a symposium entitled "Chemical Engineering in the Process Industries" sponsored jointly by the Philadelphia-Wilmington section of the American Institute of Chemical Engineers and the Department of Chemical Engineering, University of Pennsylvania. Designed for chemical engineers at all levels, students who must choose their fields of endeavor, and management men who must organize and direct the co-ordinated activities of various engineering teams, the book emphasizes the varied roles of the chemical engineer in industry, and how various phases of research are integrated to produce the best over-all result.

## Reports

**Additives and Molybdenum Disilicide** Effects of Some Metal Additions on Properties of Molybdenum Disilicide. *H. A. DeVincentis and W. E. Russell, May 1954. NACA RM E54B15, 22 pp, diagrams, photographs, 6 tables. Available from National Advisory Committee for Aeronautics, 1724 "F" St., N.W., Wash. 25, D.C.* The report covers investigations of the effect of the addition of approximately 6% nickel, cobalt, or platinum on some properties of molybdenum disilicide. The additions lowered the modulus-of-rupture strength, decreased resistance to oxidation at higher temperatures, and did not affect the thermal shock resistance.

**Overstressed Steel** Statistical Study of Overstressing in Steel. *G. E. Dieter, G. T. Horne and R. F. Mehl, Carnegie Institute of Technology, Apr. 1954. NACA TN 3211, 34 pp, diagrams, photographs, 7 tables. Available from National Advisory Committee for Aeronautics, 1724 "F" St., N.W., Wash. 25, D.C.* Material studied was SAE 4340 steel. The first part of report covers the effect of microstructure on the fatigue damage produced by overstressing. Fatigue damage was measured by the percentage decrease in fatigue life at the test stress for specimens subjected to various cycle ratios of fatigue damage at the pre-stress. Second part covered the effect of a certain amount of overstressing on the endurance limit.

*(Continued on page 180)*

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YOU'LL LIKE everything about this new family of Taylor paper-base laminates—including their price. They're a new kind of hot-punch laminate, uniform all the way through, with no surface overlay of resin.

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# Contents Noted

## Reports continued

**Resistance During Strain in Fine Wires** Electrical Resistance Changes in Fine Wires During Plastic and Elastic Elongation. *E. W. Kammer and T. E. Pardue, U. S. Naval Research Laboratory, Oct. 1948. PB 113035, 22 pp, diagrams, graphs. Available from Library of Congress, Publication Board Project, Wash. 25, D. C. Microfilm $2.00, photostat $3.75.* Investigation covers iron, nickel, and platinum, as well as fifteen alloys readily available in the form of fine wire. Strain sensitivity in both the plastic and elastic ranges has been determined from the slope of the resistance-strain curve.

**Valves: Materials and Coatings** Salt Water Valve Stems and Trim. Fifth Report on Alternate Materials: Review of Material Specifications for Bureau of Ships by the Advisory Committee on Sea-Water Valves, A.S.M. of the Minerals and Metals Advisory Board. *National Research Council, Division of Engineering and Industrial Research, Minerals and Metals Advisory Board, Dec. 1953. PB 113118, 16 pp, table. Available from Library of Congress, Publication Board Project, Wash. 25, D. C. Microfilm $1.75, photostat $2.50.* Covers materials, specifications, and corrosion resistant coatings for valves as well as substitutes for monel metal.

**Plastic Strain Measurement** Analysis of Plastic Behavior of Metals with Bonded Birefringent Plastic. *J. D'Agostino, D. C., Drucker, C. K. Liu, Brown University, Graduate Division of Applied Mathematics, Providence, R. I., Oct. 1953. PB 112909, 24 pp, photographs, diagrams, tables. Available from Library of Congress, Publication Board Project, Wash. 25, D. C. Microfilm $2.00, photostat $3.75.* As a means of measuring the plastic strains on the surface of metal, sheets of photoelastic material were bonded to the metal parts. In one procedure the entire assembly of metal and plastic was heated to obtain low modulus and linear response from the plastic as in the freezing method of photoelasticity. In the other, the plastic chosen was of the flexible type so that it could follow large strains at room temperatures. Techniques of bonding with adhesives and casting the plastic

directly on the metal were explored. In addition the photoelastic properties on a number of plastics including the adhesives at room and elevated temperatures.

**Riveted Aluminum Joints** Results of Shear Fatigue Tests of Joints with 3/16-in. Diameter 24S-T31 Rivets in 0.064-in. Thick Alclad Sheet. *Marshall Holt. Addendum No. 1. U. S. National Advisory Committee for Aeronautics, Sept. 1953. PB 100197s, 9 pp, graphs, tables. Available from National Advisory Committee for Aeronautics, 1724 "F" St., N. W., Wash. 25, D. C.* The work was carried out by the Aluminum Research Laboratories, Aluminum Company of America.

Comparative Efficiency in Bending of Structural Elements of Various Designs and Solidity. *George Gerard, New York University, College of Engineering, Apr. 1952. PB 113070, 86 pp, diagrams, graphs (part fold), tables. Available from Library of Congress, Publication Board Project, Wash. 25, D.C. Microfilm $3.75, photostat $11.25.* The analyses specify optimum core properties for various types of sandwich construction under bending loads, and also the optimum rib, post, frame or web spacing for various other types of construction. Results are discussed in terms of torsional strength or rigidity requirements, shear strength requirements and other factors.

**Materials in Skin-Stringer Panels** Data on the Compressive Strength of Skin-Stringer Panels of Various Materials. *Norris F. Dow, William A. Hickman, and B. Walter Rosen, U. S. National Advisory Committee for Aeronautics. PB 112870, 49 pp, photographs, diagrams, graphs, tables. Available from National Advisory Committee for Aeronautics, 1724 "F" St., N. W., Wash. 25, D. C.* Flat skin-stringer compression panels of stainless steel, mild steel, titanium, copper, four aluminum alloys and a magnesium alloy were tested. Results show the effect of variations in the yield stress, Young's modulus, and both yield stress and Young's modulus for constant yield strain on the buckling, and load-shortening characteristics of the panels.

news of ENGINEERS COMPANIES SOCIETIES

## News of Engineers

**G. S. Brown** has been appoin assistant manager of research, P Corp.

**Gerald Reinsmith** has been pointed factory manager for Nar Metlbond Co., Chino, Calif.

**Kurt S. Sealander** has joined supervisory staff, Hills-McCanna C Foundry Div., in the capacity chief metallurgist. Mr. Sealander formerly chief metallurgist of Magnesium Foundry Div., Alu num Co. of America.

**Sven O. Beckman** has been pointed vice president in charge operations of Autograf Brush Plastics Co., Inc.

**Whitley C. Collins** was elec president and chief executive offi of Northrop Aircraft, Inc., succe ing the late **General Oliver P. E ols.** Mr. Collins has served as a rector of Northrop since June, 19 He is also president of the Rad plane Co., a wholly-owned subsi ary of Northrop.

**George R. Foster** has been pointed manager of the Stain Steel Div., General Sales De United States Steel Supply Divisio U. S. Steel Corp.

**Rankin H. McDaniel** has be named general production super tendent, Manufacturing Div., So Aircraft Co. **L. C. Rothchild** h been promoted to assistant gene production superintendent and C. **Grantham** has been named produ tion superintendent of Building 1

**R. A. Kimes,** former manager American Machine & Foundry Co General Engineering Laborator has been named director of engine ing of the AMF Electronics Di Boston.

**Robert B. Young** has been pointed supervisor, Advance De opment Unit, General Electric C Alkyd Products Engineering, Che ical Materials Dept.

**Joel Hunter** has been elec president of Crucible Steel Co. America to succeed **William Colvin** who is retiring.

**Robert M. Norton** has be elected vice president and Myron

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## news of | ENGINEERS

Higgin assistant vice president of Hanson-Van Winkle-Munning Co. Both men will continue their responsibilities as sales manager and technical director, respectively.

Dr. **William L. Evers,** who has been assistant manager of Celanese Corp.'s Summit, N. J., Research Laboratories in charge of Plastics Division Research, has been named assistant to the technical director of the Plastics Div. with offices in Newark, N. J. Dr. **O. V. Luke,** formerly chief physical chemist of the Clarkwood, Texas petroleum chemical laboratory will succeed Dr. Evers.

Brig. **Gen. Oscar J. Gatchell,** U.S.A. (Ret.), former professor and head of the Dept. of Mechanics, United States Military Academy, has been named technical assistant to the vice president in charge of engineering, American Machine & Foundry Co.

**Donald C. Burnham** has joined the Westinghouse Electric Corp. as vice president in charge of manufacturing. Mr. Burnham succeeds **T. I. Philips,** who is retiring after 39 years of service. Mr. Burnham was formerly with General Motors where he recently held the positions of manufacturing manager and assistant chief engineer of the Oldsmobile Div.

**Walter Pascoe** has been appointed assistant research laboratory director, the Atlas Mineral Products Co. Other recent appointments were: **Willis Thomas,** formerly of the Trojan Powder Co., has been appointed research chemist for the Thermoplastic Structures Div.; **David Reinert,** formerly of Atlas Powder Co. has joined the company as research engineer in the Cellular Plastics Div.

**Don Ray Rowe,** chief production engineer of the Friden Calculating Machine Co., Inc., whose long career includes association with the Wright Brothers and C. W. Kettering, has retired.

**A. L. Topp** has been appointed vice president, engineering, A-P Controls Corp.

**T. R. Dreyer** has been appointed divisional vice president and general manager of American Machine & Foundry Co.'s Manufacturing Div.

Charles **W. Sanford** has been elected vice president, manufacturing, Jack & Heintz, Inc.

*(Continued on page 186)*

## news of | ENGINEERS

**Eugene B. Hotchkiss** has been named a vice president of Vitro Corp. of America. Mr. Hotchkiss will be in charge of new products.

**Jack E. Bolt** has been appointed application engineer in the Phenolics Engineering Unit, Chemical Materials Dept., of General Electric Co.'s Chemical Div.

**John E. McCauley,** president, Birdsboro Steel Foundry and Machine Co., has been elected chairman of the board and chief executive officer. **G. Clymer Brooke** was promoted from executive vice president to president to succeed Mr. McCauley. **James M. Heppenstall** was advanced from treasurer to vice president and treasurer, and **Arlan L. Wentzel,** former assistant vice president and works manager, was made vice president and works manager.

**Harry K. Taylor** was named assistant vice president in charge of operations for Jessop Steel Co.

**Frederic H. Holt** has been appointed general manager of the Appliance Control Dept., General Electric Co.

**Dr. Willis A. Gibbons,** associate director of research and development, has retired from United States Rubber Co. after more than 41 years of service. Dr. Gibbons' major developments include: latex dipping of tire cord, a new test for vulcanization, and the manufacture of rubber thread and other products directly from latex.

**Walter Siegerist,** president and chief engineer, the Medart Co., has been elected a Fellow of the American Society of Mechanical Engineers. Mr. Siegerist is internationally known for his work on mechanical methods of straightening all types and shapes of metals, and the centerless turning of bars, billets, and tubes.

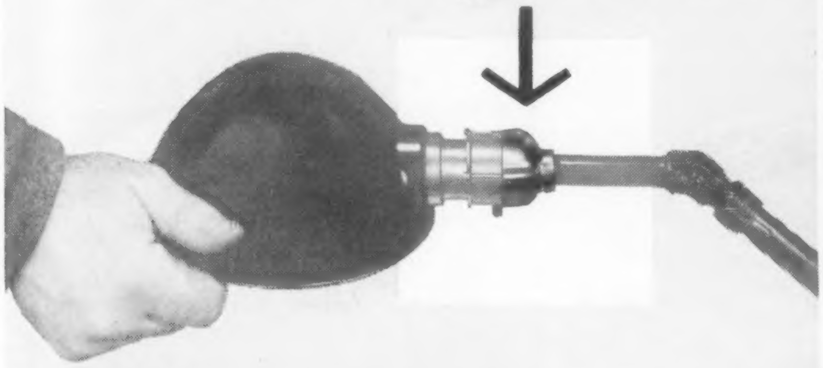
**Herman Weisberg,** mechanical engineer of Public Service Electric and Gas Co., has been elected a Fellow of the American Society of Mechanical Engineers. Mr. Weisberg has made outstanding contributions to the power-generating field.

**Carroll Cone** has been appointed chief engineer of the Industrial Divisions, and **William H. Dailey** has been appointed chief engineer of the Steel Mill Division, Surface Combustion Corp.

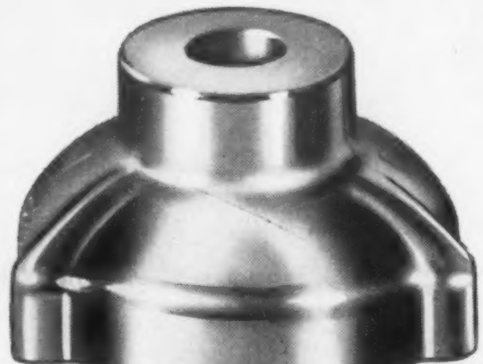
*(Continued on page 188)*

# ZINC

*die casting*
*made this part better*



*both strengthwise*
*and for finish*



THE applications of zinc die castings in industry and the home are ever-widening, the extent of their uses expanding with every day that passes.

Take this small part that has corrected a WEAK SPOT in the socket-end of an electrical fixture. Only a very small part, yet it plays a BIG PART TODAY in greatly improving the quality of a product.

Yes, zinc die castings offer manufacturers tremendous possibilities in marketing of entirely new products and in product improvements.

We want to cite to engineers this simple example of what zinc die castings can do and to remind them ADVANCE is an important source from standpoints of cost and service. Write us. Solving your manufacturing problems is part of our service.

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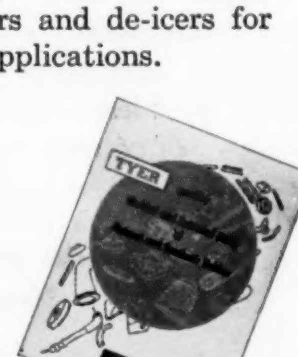
## ...Hamilton Standard, too, Relies on Tyer Research in Rubber

Mr. E. Garaventa, Chief Development Engineer, Hamilton Standard Division of United Aircraft Corporation, Windsor Locks, Conn., and Mr. L. H. Bardach, Tyer Sales Engineer, discuss devices utilizing molded rubber compounds which de-ice propeller blades efficiently and dependably.

Preventing the formation of ice on propeller blades demands both meticulous selection of materials and advanced production techniques. Rigid inspections must be made, at each stage, to safeguard the final product from both visible and hidden defects.

Tyer's technical staff, working closely with Hamilton Standard engineers, who design the propellers used on 90% of the nation's commercial aircraft, plays a leading role in the design of wire-element type heaters and de-icers for both external and internal applications.

**If you have a problem involving rubber, call in a Tyer Sales Engineer or write for our "Molded and Extruded Rubber" catalog, Dept. 93.**




# Tyer

**RUBBER COMPANY**

*The Unusual in Rubber Since 1856*

**ANDOVER, MASSACHUSETTS**

For more information, turn to Reader Service Card, Circle No. 451

## news of | ENGINEERS

**Selden E. Doughty** has been appointed production manager of the Alloy Tube Div., Carpenter Steel Co. Before his appointment, Mr. Doughty was chief metallurgist at the Union, N. J. mill.

**A. H. Merschel,** for seven years assistant to the president of Chrysler Corp.'s Amplex Div., is retiring.

**Carroll Marquard** has been appointed manager of production engineering for the Central Metal Div., Continental Can Co.

**R. C. Allen** has been named director of mechanical engineering, and **L. J. Linde** has been named director of electrical engineering, General Machinery Div., Allis-Chalmers Manufacturing Co.

**Arch J. Cochrane** has been appointed manager of Chicago district operations, The Youngstown Sheet and Tube Co., succeeding **B. M. Stubblefield** who recently retired.

**Donald H. McCuaig** has been appointed manager of application engineering, Air Conditioning and Refrigeration Div., Worthington Corp.

**Richard C. Cole** has joined Vitro Uranium Co., a division of Vitro Corp. of America as plant manager of its uranium ore refinery.

**Dr. William Alfred LaLande, Jr.** and **Edward F. Beale,** were elected vice presidents, Pennsylvania Salt Manufacturing Co. Dr. LaLande will continue as manager of research and development and Mr. Beale will continue as company treasurer.

**Hugo Lorant,** vice president and member of the board of Hydropress, Inc., has been elected senior vice president. **Paul Mayer** was named assistant vice president of the company.

**Dr. Glen W. Wensch** has been appointed Vitro Corp. of America's metallurgical engineering representative in the atomic power reactor project which is now under study by 26 associated firms, and led by Dow Chemical Co. and Detroit Edison Co. Dr. Wensch came to Vitro after serving for two years as chief of the materials branch of the Atomic Energy Commission at the Savannah River Operations Office in Georgia. He joins **Alton P. Donnell** of Vitro who has acted as coordinator for the Dow Detroit studies, and who recently became project manager for the activity.

*(Continued on page 191)*

## news of | ENGINEERS

Walter J. **Maytham,** Pacific Coast regional manager for the Company's Apparatus Div.; **Dale McFeatters,** director of information services for the company, and **Otis O. Rae,** southeastern regional manager of the Apparatus Div., have been elected vice presidents of Westinghouse Electric Corp.

**Walton A. Lean** has been promoted to vice president and technical director, Wilcolator Co.

**Dr. B. M. Sedalia** has joined the Research Laboratory of the Titanium Alloy Manufacturing Div., National Lead Co.

Stanley **R. Hood** has been appointed to head a new Thermostat Metal Division recently established by American Silver Co., Inc.

**E. B. Jones** has been appointed chief engineer in charge of estimating and engineering in Lindberg Engineering Co.'s newly formed Field-erected Equipment Div.

## news of | COMPANIES

The **Tubular Products Div., Babcock & Wilcox Co.,** has announced completion of an expansion program which will increase by nearly 40% the productive capacity for stainless steel tubular products.

**Resistoflex Corp.** will open a new office and assembly station at 4414 West Jefferson St., Los Angeles 16.

**Continental Blacks, Inc.** recently opened its new carbon black plant in Ponca City, Okla.

**Ferro Corp.** has announced the purchase of the **Louthan Manufacturing Co.,** East Liverpool, Ohio, from **Harbison-Walker Refractories** Co. Harry T. Marks, vice president of Ferro, will be the new president of the Louthan Div. of Ferro. The new division will produce electrical porcelain insulators, refractory specialties for firing pottery and for the foundry field, and other ceramic products.

**American Machine & Foundry Co.'s** executive, administrative and sales offices, are now located on four floors of the new AMF building 261 Madison Ave., New York 16, N.Y.

Plastics **Products Corp.** has announced a new plastic molding plant designed specifically for manufactur-

For more information, Circle No. 406 →

## news of | COMPANIES

ing a wide variety of plastic products reinforced with fiber glass to be opened in Bedford Heights, Ohio late this month.

**Hamer Oil Tool Co.** has changed its company name to Hamer Valves, Inc.

**New Process Metals, Inc.** has completed its expansion program with the opening of a new, enlarged plant, located at 45-65 Manufacturers Place, Newark, N.J.

**Industrial Filter and Pump Manufacturing Co.** has established a $5000 annual fund at Illinois Institute of Technology to assist liberal arts students in acquiring an engineering education.

**Allied Chemical & Dye Corp.** has completed its ammonia production facilities of its new nitrogen plant at Omaha, Neb. Early completion of the urea production facilities is expected. It is estimated that the plant will cost upwards of $25,000,000 when completed.

**Air Reduction Co., Inc.** has approved the acquisition of the assets and business of the **Colton Chemical Co.,** in exchange for Air Reduction common stock. It is anticipated that the Colton Chemical Co. will operate as a division of Air Reduction with headquarters remaining in Cleveland.

**General Electric Co.'s Plastics Dept.** has announced the creation of an Operations Research section within its management group. K. O. William Sandberg was named manager, operations research.

**Rolle Manufacturing Co.** has announced licensing for both the Al-Fin and Osbring Casting processes.

**Durez Plastics & Chemicals, Inc.** has announced the start of excavation for a new building at its North Tonawanda plant. This new $100,000 unit will be equipped for piloting new chemical processes and materials developed in the company's research laboratories toward future full-scale plant production.

**Goshen Rubber Co., Inc.** has announced completion of its new plant for fabricating precision-molded silicone parts.

**Reynolds Metals Co.** has completed its new merchant mill at Sheffield, Ala. The new mill at a cost of one and three-quarter million dol-

# news of | COMPANIES

lars, has the capacity to produce 36 million pounds of aluminum merchant wire, rod and bar products annually.

**Micromatic Hone Corp.** recently celebrated its 25th Anniversary.

**Eutectic Welding Alloys** Co. of **Canada Ltd.** has acquired premises at 3150-37 Street, Ville St. Michel, Montreal, P.Q., for the manufacture of its special purpose alloys in Canada.

**Foam King, Inc.** has completed its research and development of a new approach in the formulation and manufacture of Foam Plastics, which they describe as Foam King products.

**Alloy Metal Wire Co. Division of H. K. Porter Co., Inc.,** has completed and is now using a new addition to its plant in Prospect Park, Penna. At the same time announcement was made that additional gas cracking capacity will be added in the near future, and a 4-high Steckel Mill is being installed to increase production of high quality nickel alloy and stainless steel strip.

**Foote Mineral Co.** is sponsoring the Second Lithium Award Program to stimulate and reward research in the uses of Lithium in ceramics. A total of $2000 in cash prizes will be awarded to authors of the best papers describing heretofore unpublished development work. The competition, open to all professional engineers, researchers, technicians and students, is divided into two classes: professional and student. Separate awards will be made for three papers in each class. Closing date for entries is Nov. 1, 1954, and all papers must be submitted by July 1, 1955.

**Westinghouse Electric Corp.** recently broke ground at Blairsville, Penna., for its new multi-million dollar metals plant. In the development and application of new metals, the Blairsville plant will work closely with the new Westinghouse Research Center now under construction about 10 miles east of Pittsburgh, and also will have limited capacity for the manufacture of special metals needed by various Westinghouse operating divisions.

**The Beaumont Iron Works Co.** has been formally merged into its parent corporation, **American Locomotive Co.**

*(Continued on page 196)*

## news of | COMPANIES

**Worthington Corp.** recently acquired through its wholly owned subsidiary, the **Electric Machinery Manufacturing Co.** of Minneapolis, the **Mullenbach Electrical Manufacturing Co.** of Los Angeles.

The **B. F. Goodrich** Co. has started manufacturing operations in Salem, Ind. The modern plant will employ about 150 men and women and will produce gaskets used principally in refrigerator manufacturing.

**International Resistance.** Co. has announced that its wholly-owned California subsidiary, formerly the **Gorman Manufacturing** Corp., will be called Ircal Industries.

**Conforming Matrix Corp.** has acquired space which will double the facilities of the manufacturing, engineering and executive departments.

**Buehler Ltd.** now occupies its new plant and offices located at 2120 Greenwood St., Evanston, Ill.

**Essak Steel & Chemical** Co. has expanded its operations in the metal cleaning field to include an expanded service department and an increased line of compounds to simplify metal cleaning and bond coating for the paint, porcelain enamel and electroplating industries.

**Universal Metal Products,** Inc. has announced completion of another phase of its expansion program with the installation of cold test chambers, high temperaure test ovens and other research and development equipment.

**Amercoat Corp.** is now occupying new executive offices and a new research laboratory recently erected at its home office site at 4809 Firestone Blvd., South Gate, Calif.

**Precision Apparatus** Co., Inc., presently located in Elmhurst, L. I., N. Y., will move its manufacturing, engineering and administrative facilities to a new plant in Glendale, L. I. by mid-summer of 1954.

**Tenney Engineering, Inc.** is now carrying on full scale operations in its new plant at 1090 Springfield Rd., Union, N. J.

**American Cyanamid** Co. has opened its new rubber chemical accelerator plant which more than doubles its present production capacity. Located at Bound Brook, N. J., the plant is devoted exclusively to the production of NOBS Special and NOBS No. 1 accelerators.

*(Continued on page 200)*

## news of SOCIETIES

**Illinois Institute of Technology** has been selected as one of six colleges and universities that may be attended by the recipient of a $500 annual scholarship established by the Maysteel Products Corp.

**New York University's College of Engineering** has opened a new laboratory for surface technology research in its Research Div. The new facility is located in Engineering Research Bldg. No. 2 at 401 W. 205th St. in Manhattan.

**Massachusetts Institute of Technology** is offering a special summer program in casting of light metals from Aug. 23 through Sept. 3. Howard F. Taylor, professor of metallurgy at M.I.T., will direct the two-week special summer program.

The **Trinks Industrial Heating Award** was recently given to five men at a banquet sponsored by the Award Committee. The award, bestowed annually by a judges' panel of industrial heating authorities, among candidates nominated by the industry for outstanding contributions to industrial heating science or economics went to the following men: William M. Hepburn, vice president in charge of engineering, Surface Combustion Corp.; Frederic O. Hess, president, Selas Corp. of America; Dr. Russell P. Heuer, vice president in charge of research, General Refractories Co.; Matthew H. MaWhinney, consulting engineer; and Lee Wilson, Lee Wilson Engineering Co.

The **American Iron and Steel Institute Medal** was awarded to two individuals at the 62nd General Meeting of the Institute held in New York. The award is voted by the board of directors of the Institute for a paper of special merit and importance—a paper read before a meeting of the Institute. William Charles Bell, company director and managing director of iron and steel production, Stewarts and Lloyds Ltd., Great Britain, received the medal for his paper, "Review of European Operating and Technical Practices". The second award went to W. A. Black, chief electrical experimental engineer, Steel and Tubes Div., Republic Steel Corp., for the excellence of his paper titled, "Ultrasonic Testing of A Large Engine Crankshaft".

**American Foundrymen's Society** elected the following officers at its recent meeting in Cleveland: Frank J.

• For more information, turn to Reader Service Card, Circle No. 419

## news of | SOCIETIES

Dost, president, The Sterling Foundry Co., was elected president; Bruce L. Simpson, president, National Engineering Co., was elected vice president. At the same meeting, the Society honored three outstanding men of industry by presenting to them the highest awards bestowed by the AFS, the Gold Medals. The three men so honored were: Thomas Evan Eagan, "For outstanding work in the development and dissemination of engineering data on the production and utilization of alloy cast irons."; Roy Arthur Gezelius, "For outstanding contributions to the steel casting industry, particularly in the development and production of cast steel armor."; Walter E. Sicha, "For extensive, valuable work on light metals casting alloys and for outstanding contributions to the Society".

**Massachusetts Institute of Technology** has announced that Metallurgical Applications of X-Ray Diffraction will be the subject of a two-week special summer program from August 2-13, 1954.

*(Meetings and Expositions on page 204)*

## Coming in MATERIALS & METHODS

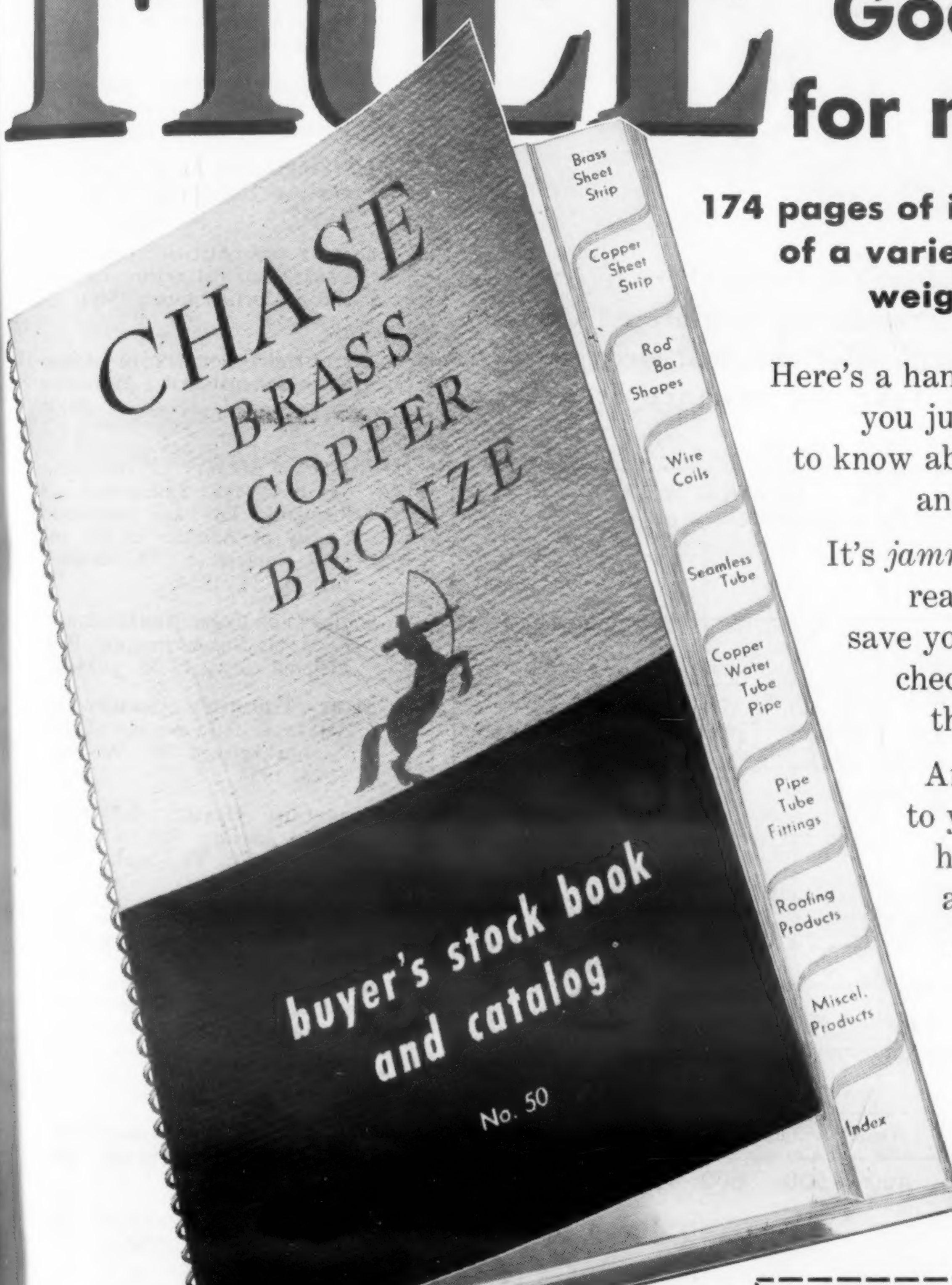
**Watch for these important M & M Manuals to appear soon in MATERIALS & METHODS:**

- **How Engineering Materials Are Affected by Nuclear Radiation—*August***
- **Close Dimension Cast Forms—*September***
- **Age Hardening of Metals—*October***
- **Adhesive Bonding of Metals—*November***
- **Properties and Applications of Clad Metals —*December***

# FREE

## Good reading for metal men!

**174 pages of illustrations and listings of a variety of products...sizes... weights...tempers...shapes!**




Here's a handy, desk-size book that gives you just about *everything* you need to know about brass, copper and bronze and now . . . stainless steel, too!

It's *jammed to the brim* with easy-to-read data. It's *thumb-indexed* to save you time. It has a how-to-order check list that's designed to take the headaches out of ordering.

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For more information, turn to Reader Service Card, Circle No. 433

## Meetings and Expositions

AMERICAN ELECTROPLATERS' SOCIETY, annual convention. New York, July 12-15, 1954.

SOCIETY OF AUTOMOTIVE ENGINEERS, West Coast meeting. Los Angeles. August 16-18, 1954.

WESTERN ELECTRONIC SHOW & CONVENTION. Los Angeles. August 25-27, 1954.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, fall meeting. Milwaukee. Sept. 8-10, 1954.

METAL POWDER ASSOCIATION, fall meeting. Hot Springs. Sept. 10-12, 1954.

SOCIETY OF AUTOMOTIVE ENGINEERS, national tractor meeting and production forum. Sept. 13-16, 1954.

INSTRUMENT SOCIETY OF AMERICA, international instrument congress and exposition. Philadelphia. Sept. 13-20, 1954.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Instruments and Regulators Div. and Instrument Society of America exhibit and joint conference. Philadelphia. Sept. 13-24, 1954.

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS, annual meeting. Philadelphia. Sept. 21-23, 1954.

STEEL FOUNDERS' SOCIETY OF AMERICA, fall meeting. White Sulphur Springs, W. Va. Sept. 27-28, 1954.

PORCELAIN ENAMEL INSTITUTE, annual meeting. White Sulphur Springs, W. Va. Sept. 29-30, 1954.

ELECTROCHEMICAL SOCIETY, fall meeting. Boston. Oct. 3-7, 1954.

SOCIETY OF AUTOMOTIVE ENGINEERS, National aeronautics meeting, aircraft production forum and aircraft engineering display. Los Angeles. Oct. 5-9, 1954.

NATIONAL FOUNDRY ASSOCIATION, annual meeting. Chicago. Oct. 6-8, 1954.

AMERICAN GAS ASSOCIATION, annual convention. Atlantic City. Oct. 11-14, 1954.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, fall meeting. Chicago. Oct. 11-15, 1954.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS, south central regional meeting. Dallas. Oct. 12-15, 1954.

SOCIETY OF AUTOMOTIVE ENGINEERS, national transportation meeting. Boston. Oct. 18-20, 1954.

**Basic Materials Conference and Exposition. Philadelphia. June 12-16, 1955.**

# News Digest

**Isotopes . . .**

continued from page 11

**Radioactive isotopes** are being used to extend our knowledge of the behavior of materials.

thermosetting phenolic molding compound was formulated which exhibited a four-fold improvement in erosion characteristics. The new material was announced by Wyman Goss, Manager of G.E.'s Phenolic Engineering Laboratory in an address to the National Plastics Exposition.

The erosion tests are capable of detecting and measuring as little as one part of metal in 20 million parts of plastic. The radioactive tracer tests were chosen over chemical spectrographic and physical test methods because the amount of metal worn on each molding cycle is almost infinitessimal. The sensitivity of the tests yields quantitative information when only a small part of the mold is made radioactive. The tests are based on the erosion of a radioactive sprue bushing from a standard transfer mold. The bushing is encapsulated and irradiated at the Brookhaven National Laboratory atomic pile and returned to Pittsfield for tests. The bushing is inserted in a standard transfer mold, which is put through a regular production cycle. The molded part, containing the small amount of metal eroded from the bushing in a single pass, is analyzed at G.E.'s Laboratory in Schenectady.

The low erosion molding compounds developed as a result of the tracer research will extend die life by a factor of two, Goss claimed. He said that a TV cabinet mold normally good for a life of 10,000 to 15,000 cycles would last for 20,000 to 30,000 pieces. The new molding compounds are now in pilot production and will be generally available during the third quarter of 1954.

The extrusion and die erosion proj-

# News Digest

ects are only two of many projects now underway using radioactive trace materials. Besides the work on erosion, Alcoa is using the technique in lubricant evaluation, corrosion resistance studies, analytical chemistry, and alloy development.

Many engineering materials can be irradiated to make them radioactive enough for use in research without impairing their original qualities. When a substance is placed in the pile it is bombarded with neutrons at high densities. Radioactivity occurs when a neutron collides with an atomic nucleus of the material under irradiation, and the nucleus gives off excess energy in the form of high energy radiation of a nature similar to that of x-rays. One difficulty in using irradiated materials is the short half life of their radioactive isotopes. Some must be used almost on the spot to take advantage of their radioactivity.

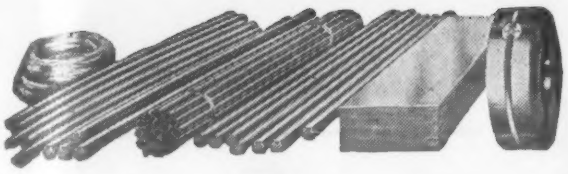
The radioactive waste from each project must be returned to a proper AEC facility for proper disposal.

## Extrusion Die Problems Discussed

Aluminum and die making industry representatives got together recently and agreed on a number of points which would lead to the improvement of extrusion die materials for aluminum fabrication. Firth Sterling, Inc. sponsored the conference in the interest of initiating a research program to develop new die materials for the aluminum extrusion industry.

The conferees agreed among themselves that they could not isolate any one single factor which contributed to the short life of dies, since failures are about evenly distributed between breakage, wear and erosion. They felt strongly that no attempts should be made to improve one characteristic of dies at the expense of another.

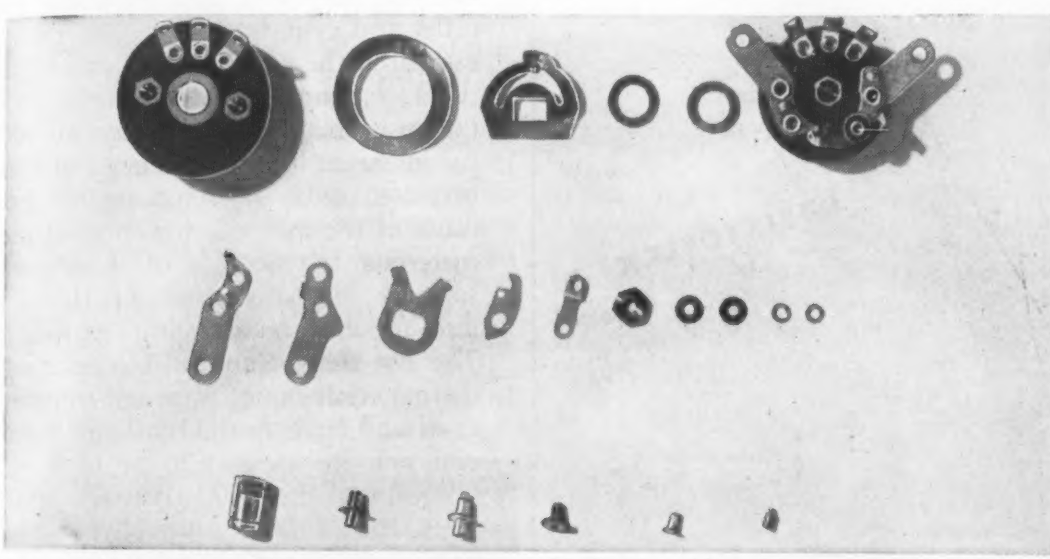
The difference in extruding characteristics between casts of aluminum leads to short die life due to large amounts of reworking required on the dies. The men felt that going to a harder die material would not be a solution to erosion because there is no practical die material with a hardness greater than aluminum oxide,



BRIDGEPORT BRASS COMPANY

# COPPER ALLOY BULLETIN

Bridgeport Brass Co. MILLS IN BRIDGEPORT, CONN. AND INDIANAPOLIS, IND.—IN CANADA: NORANDA COPPER AND BRASS LIMITED, MONTREAL



Parts of ⅝" diameter miniature volume controls used in hearing aids and in many other applications. Courtesy of Centralab, a Division of Globe-Union Inc., Milwaukee, Wisconsin.

## Copper Alloys Play Important Role In Miniaturization Trend

Throughout the electronics industry, the trend is to smaller, lighter, more compact assemblies. Hearing aids, for example, must incorporate all the elements of a radio amplifier in a package not much larger than the average cigarette case. Portable communications equipment like radio sets for aircraft and automobiles, miniature personal radios, walkie-talkie units, airborne radar receivers all must be designed so that every possible extra inch of space and ounce of weight can be trimmed off the finished product.

**Miniature Volume Control**

Illustrated above with its copper-base alloy components is a volume control no bigger in diameter than a dime. This type of control has a rating of 1/10 watt and is obtainable with resistance ranges of from 0 to 500 ohms and on up through 10 megohms. It is probably one of the smallest volume controls commercially available. It is currently being used as a component in many hearing aids, test instruments, miniature radios, microwave sets and other miniaturized apparatus.

**Copper-Base Alloys Excellent for Precision Parts**

Copper-base alloys are preferred for many electrical and electronic applications because of their fine properties. Conductivity, good corrosion resistance, ability to withstand severe forming operations, high wear resistance, excellent plating and finishing properties explain their wide use in the many thousands of products with which we are familiar.

Many of the parts in this control are made of brass. Some are plated with either nickel or cadmium for increased wear resistance or silver for improved contact characteristics.

Among the parts made from brass rod are the contact blade pivot pin, the mounting studs, the shaft, rivet, hex screw and nuts. The terminals were made from yellow brass strip which is easily stamped and formed. The spacers and washers were also made from brass.

**Phosphor Bronze Vital in Electronics Equipment**

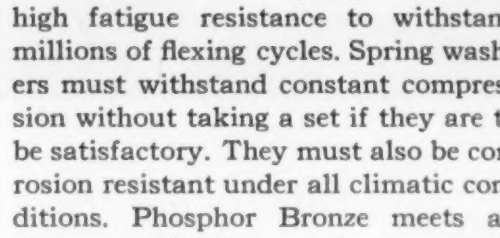
In complex assemblies like these volume controls and switches, satisfactory performance depends on each tiny part, especially those spring parts used in making mechanical and electrical contacts. For this reason, the selection of the correct alloy, temper, and gauge is most important.

The contact spring washer and spring pivot pin washer in the tiny volume control illustrated were made of Phosphor Bronze Grade C, approximately 92% copper, 8% tin, and 0.1% phosphorus. Supplied for these applications 8 B&S numbers hard, the material has a tensile strength of about 112,000 psi. It is widely used throughout the electronics industry because it combines superior spring properties as well as conductivity and high corrosion resistance.

Parts like contact springs must have high fatigue resistance to withstand millions of flexing cycles. Spring washers must withstand constant compression without taking a set if they are to be satisfactory. They must also be corrosion resistant under all climatic conditions. Phosphor Bronze meets all these qualifications and yet can be stamped and formed into precision parts. That is why Phosphor Bronze is in such wide use in the fields of radar, radio, television, sound reproduction and amplification, and in all types of electronic and electrical equipment and controls.

**Bridgeport Brass Service**

Bridgeport Brass supplies copper-base alloys—in strip, rod, tubing, and wire—used in the electronics field. Our Laboratory will be glad to assist you in the selection of proper alloys for your applications. Write for Bridgeport Brass Technical Handbook for properties and applications of copper-base alloys. Call or write the Bridgeport District Office nearest you. (714)



Parts of electronic switch and assembled switches. Courtesy of Centralab, Milwaukee, Wisconsin.

For more Information, turn to Reader Service Card, Circle No. 479

## News Digest

which is the cause of almost all scratching of dies in aluminum extrusion.

While pressures in extrusion presses run from 60,000 to 140,000 psi, all this pressure is not exerted on the die face due to friction in the material extruded and between the billet and cylinder walls. The group estimated the actual pressures on the die face range from 40,000 to 75,000 psi, and will not exceed 80,000 psi in the near future. They felt that breakage most often occurs not because of the inherent weakness of die materials, but because of inadequate support given portions of the die due to the shape being extruded. The hot yield strength of supporting die materials is not sufficient in many cases and leads to die breakage. General practice appears to be to use a hot worked die steel hardened to 46 to 52 Rockwell C, although one user preferred a high speed steel of 35 Rockwell C for extrusion of tubing only.

Dies in present use are from about 4-in. o.d. to 30-in. o.d. and range in thickness from $\frac{3}{4}$ to 4 in. Each extruder at the conference seemed to have his own preference for ratio of thickness to diameter.

The conferees all expressed a desire for information regarding the hot yield strength of die materials in the temperature range from 700 to 1000 F. Extrusion billets are generally heated to between 700 and 900 F, and temperature increases during the extrusion process. Estimates placed extrusion temperatures as high as 1150 F. Since steels are annealed by the temperature of extrusion, the extruders would like to have a die steel which would retain a hardness of Rockwell C 50 at 1000 F and would be able to withstand the corrosion of hot aluminum better than present grades. They called for surface finish characteristics within 8 micro in. rms. Thermal conductivity could stand some improvement, but an increase of 10 or 15% would be the limit. Thermal shock presents little problem. The ability to be recut by the user was considered unimportant, as was cost (within the limitation that the relative cost per pound of extruded products must be cheaper for a new steel).

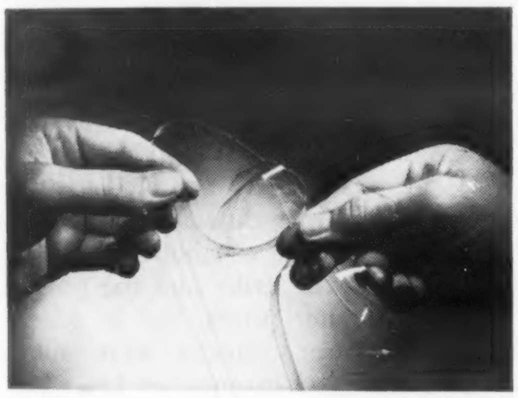
One of the most difficult problems facing the industry is a suitable material for dies having tongues with large length to width ratios. At pres-

# CORNING GLASS BULLETIN

FOR PRODUCT DESIGNERS

***Ribbon glass by the yard.*** Here's a glass that's a thousandth of an inch thin and in small widths it's flexible as—well, a ribbon. You can twist it, roll it, wrap it around your arm without cracking it. It comes in any length you want—inches, yards, miles.

Actually ribbon glass isn't a single glass. We can make it of several different compositions according to what you need it for. Originally we developed it to take the place of mica in electronic capacitors of which there are several in your radio and TV sets and in any other piece of electronic equipment you can name. As mica is formed in layers, it is subject to cleavage in the plane parallel to lamination; ribbon glass being homogenous is easily workable. This is just one advantage of this glass in capacitors.



Medical scientists have found a quite different use for ribbon glass—as microscope slide covers. These are the wafer-like pieces of glass that are used to cover blood smears and the like for examination under the microscope. In this case ribbon glass can be made clearer, flatter and more free of bubbles and striae than previously made glasses.

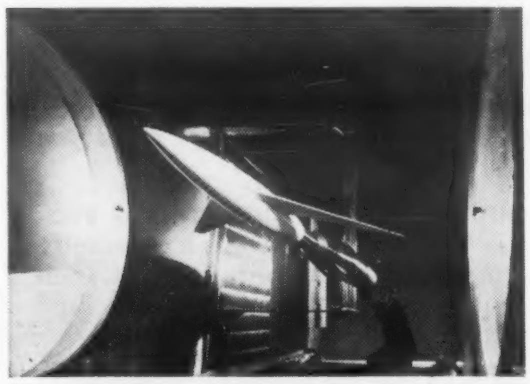
▶ Seems as if this unique stuff should be good for a *lot* of things, but *what* (other than electrical and laboratorial) probably lies in the laps of imaginative designers. Would you like us to send you a little strip to play with?

***Two tons—on the nose!*** If you called for them, we could, with reasonable speed, provide you with a king-size pair of glasses. The lenses alone would weigh in at a hefty two tons.

Since it's no mean feat to balance "specs" like that on your nose, we don't have too much call for them. Still, we have filled one order and are prepared to fill another any time they're needed. You might be interested in this little story, not as a prospect for such outsized eye-wear, but because it might suggest a new approach to some design or manufacturing problem of your own.

Our aerodynamic friends find wind tunnels valuable instruments in developing new and better products. Naturally, to make the most of said wind tunnels, it's necessary to see and photograph what's going on inside. That's what led us to build the windows you see in the picture below. Weighing nearly a ton each, these giant disks are of finest optical quality—a very necessary feature since the scientists and engineers must make precise observations through them. More remarkable still is the fact that these optically perfect pieces of glass withstand the enormous forces built up by air moving at nearly *twice the speed of sound.*

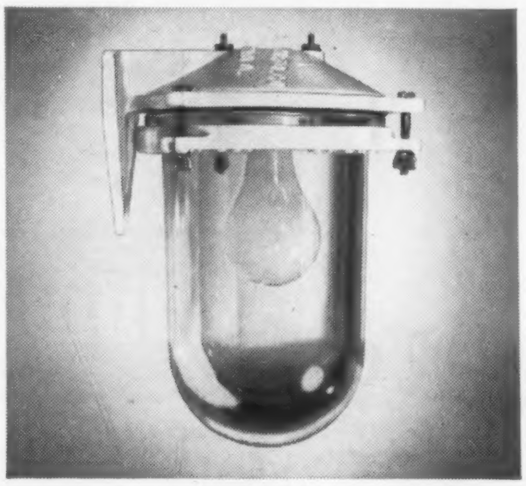
▶ If heretofore you've looked on glass as a somewhat fragile material of limited use, these windows to the supersonic world may give you food for thought. However, we like to admit that, despite the unique quality of these panes, they are just one of countless special-application products devised by Corning engineers working with customers' problem children. So, even if aeroplanes or ranting winds aren't your responsibility, talking over *your* problem with the men at Corning could very well lead to a profitable solution.



***In defense of light.*** Throwing light on a subject is often easy—*keeping* it there may be something else again.

A good, if unusual, case in point is made by a manufacturer of our acquaintance who makes shot blasting equipment for cleaning metal castings. Unfortunately the shot which cleaned the castings also played havoc with the light bulbs in the equipment. For a while it looked like a choice between constantly replacing shattered bulbs or working in the dark—neither offering a satisfactory solution.

The big question—could the castings be cleaned while being seen? Turns out the answer was YES. Corning was able to develop a special glass globe to shield the light bulbs from the metallic barrage. Made of clean PYREX brand glass No. 7740, these half-inch thick, abrasion-resistant globes let through plenty of light and, by saving bulbs from speedy annihilation, earn their keep over and over again.



▶ If by chance some production problem centers your interest on protecting light bulbs perhaps we have the specifications, solution and can quote prices. On the other hand, if our little story serves only to give you an idea of what a rugged material glass really can be, we encourage you to refresh your memory on some of its other useful attributes, which you will find described quite lucidly in our Bulletin IZ-1, "Glass—its increasing importance in product design." We'd be delighted to send you a copy.

**Frankly, we're being amazed continually (almost) by the ingeniousness of people who come up with ideas we'd never in all time think of for putting glass to work. We've worked with hundreds of folks and we'd like to work with you, if you have a stubborn materials problem that glass might eliminate. We've got research experience, application experience, production experience, and plenty of facilities. It'd be a pleasure to put them to work for you on any likely problem or product.**

*Corning means research in Glass*

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## News Digest

ent the maximum length to width ratio for tongues is about 4 to 1, but extruders are constantly asked to produce forms with ratios as high as 10 to 1. A suitable die steel for such an application would have to have an increased modulus of elasticity, better resistance to shear and torsional bending and a lower coefficient of friction.

The group discussed the necking of mandrels for internal openings in extruded products. It was considered likely that the necking occurs at the hottest point on the mandrel and is an elongation phenomenon resulting from tension stresses due to friction of aluminum moving along the mandrel.

## 20% of Steel to Construction

The steel industry looked healthier in June than at any other time in 1954, as mills operated slightly above 70% of capacity. Part of the upturn may be attributable to hedging against a strike and the possibility of higher prices, but in general, manufacturer's stocks were sliding into line and inventories looked less forbidding.

Construction and contractors products have emerged this year as more important in maintaining the demand for steel than ever before. In the first quarter of 1954 shipments of finished steel to the building and construction industry were about three million tons, or roughly equivalent to the amount shipped in the first quarter one year ago. As a result, the percentage of steel shipped to the construction industry is higher than at any time since 1940. In March this year, 20% of total steel shipments went to contractors and builders.

The rising trend of activity in highway projects, including bridges, and a sizeable number of projects involving office buildings, shopping centers and auditoriums has resulted in a large demand for heavy structural shapes. Shipments of heavy structural steel in the first quarter of this year were about 120,000 tons higher than in the same part of last year. Steel piling shipments were slightly higher, while steel plates and reinforcing bars were off somewhat.

*(More News on page 214)*


**NOW**— Frasse, as distributor for the Reynolds Metals Company, can furnish your aluminum requirements direct from warehouse stock.

Aluminum rods, bars, wire, sheets, plates, tubing and extruded shapes in a complete range of sizes and a wide variety of grades can now be supplied by Frasse . . . quickly and efficiently.

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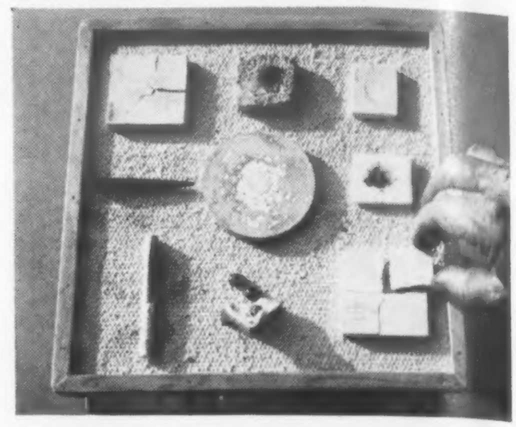

**Ceramic materials** tested in solar furnace.
Some of the materials crack and flake due to thermal shock when moved into the furnace's focal point.

**The 120-in.** aluminum mirror collects rays from the sun and concentrates them on a dime size focal point. When sky conditions are ideal, the furnace develops a temperature of 8500 F, approximately 85% of the temperature of the sun's surface.

## Sun Fires Research Furnace

A solar furnace capable of generating temperatures up to 8500 F is providing valuable data in high temperature research projects at Convair's San Diego Division. The furnace, a 120-in. parabolic polished aluminum reflector, focuses the sun's rays on an area only 5/16 in. in diameter. Under ideal sky conditions, temperature at the focal point reaches 85% of the temperature of the sun.

The solar furnace offers several advantages over more conventional types. Heating occurs in an oxidizing atmosphere under conditions of controlled purity with no interference from gases or magnetic fields. The open construction of the furnace provides good accessibility and observation during heating and cooling, and temperature is controlled


*...with*

# CRUCIBLE

*stainless steel castings*

A large shell manufacturer had a serious problem. Cast iron shell holders, used in the hardening furnaces where temperatures go up to 1600 F, burned out and crumbled. Frequent replacements and costly shutdowns were necessary.

The casting shown above (Crucible Type 309) proved the answer to the problem. This sand casting of heat-resistant stainless steel, and hundreds like it, are outperforming their iron predecessors . . . and seem headed for a practically limitless life.

It will pay you, too, to take full advantage of Crucible castings. They are available in a wide range of stainless, tool and special alloy grades, and to meet conditions of corrosion, high-temperature, wear or abrasion. And Crucible—leading producer of special steels—controls the steel used, from furnace to finished casting. You can be sure of sound, uniform castings of the highest quality when you *call Crucible*.


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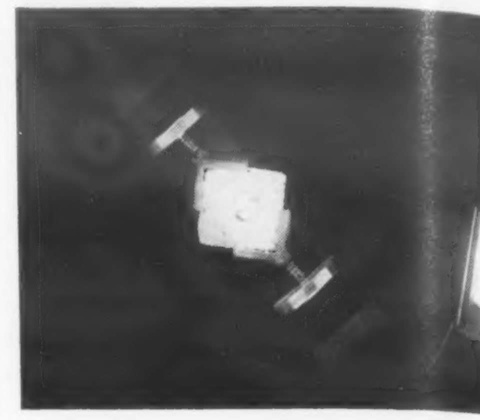
# News Digest



**A ceramic specimen** in Convair's solar furnace is shown here with the material beginning to melt at the dime-size focal spot.

simply by shading off part of the mirror surface by means of a cylindrical barrel within which the specimen is mounted.

Position of the specimen is controlled by motor driven screws on the specimen holder. In order to keep the focal point in one location, the mirror is mounted in a gimbal ring with its axis parallel to that of the earth, and a mechanical timing drive similar to that used on large telescopes keeps the mirror turning with the sun. An opening 22 in. in diameter in the mirror directly beneath the specimen allows full observation of the focal spot from a position behind the mirror. A telescope mounted at this position permits detailed observation of melting at magnifications of 20 dia.

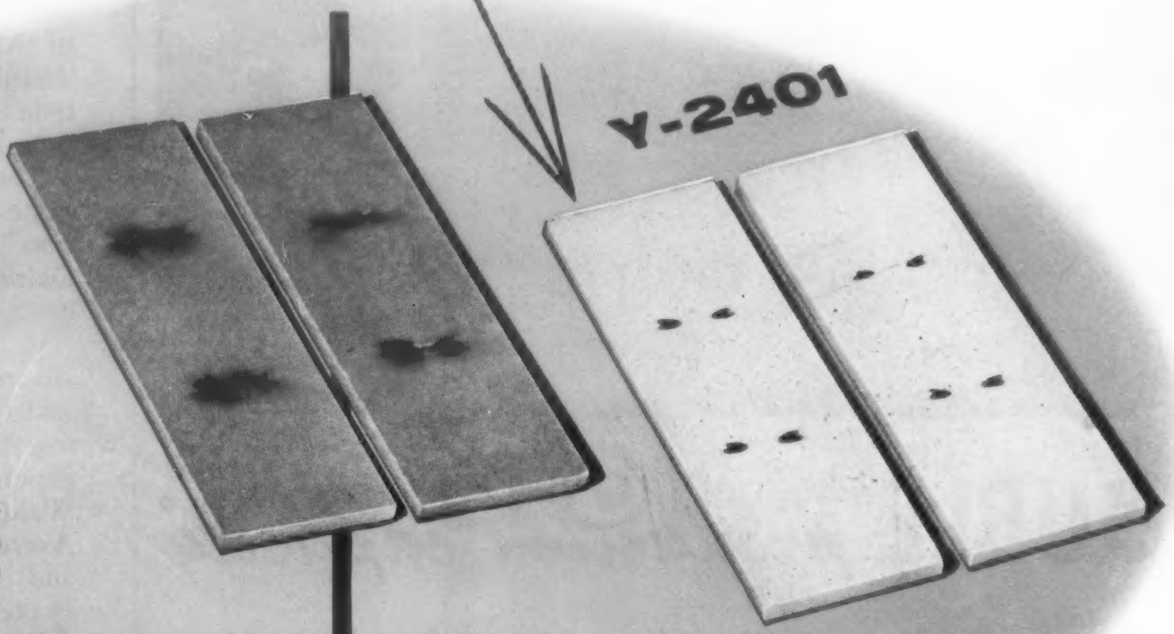
The fair weather furnace will be mounted on a mountain near San Diego to take advantage of high altitude sky conditions.

## AWS Meeting on Welding Progress

Forty papers covering the application of welding to a variety of materials were heard at the second National Spring Meeting of the American Welding Society in Buffalo, May 4-7. The technical meetings were held in conjunction with the second AWS Welding Show, where nearly 8000 technical and management personnel viewed the latest developments in welding processes and equipment.

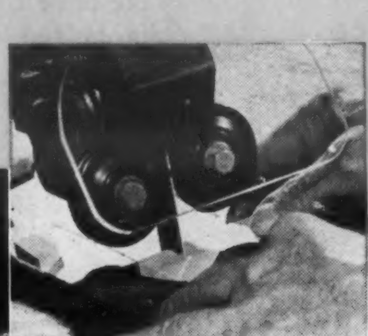
Three of the papers were concerned with the joining of titanium. In the paper, "High Temperature Alloy Fusion Brazing for Titanium and Titanium Alloys," R. A. Long and R. R. Ruppender, Ferrotherm Co., described new nickel-titanium brazing alloys which may make furnace brazing of

# this new and significantly superior Phenolite Laminated Plastic

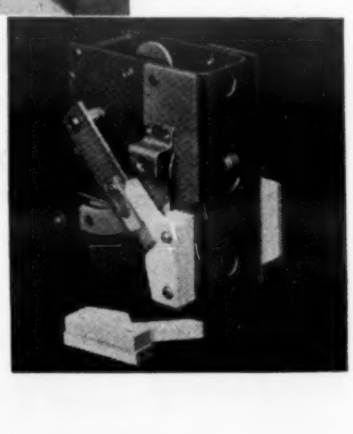



Here's a test showing the superior arc resistance of this new melamine-polyester material—Y-2401 by name. All samples were subjected to 5 arcs of 15 KV, 30 milliamps, through a ⅜" gap at a rate of 113 arcs per minute. Note how Y-2401 (two samples at right) showed only minor burns whereas Standard Grade XX phenolic material (at left) was deeply carbonized across the arc, resulting in conducting paths.

## EXCELS IN ARC RESISTANCE
## ...IN MACHINABILITY
## ...IN ELECTRICAL PROPERTIES



With an ordinary band saw, operator saws out a Y-2401 part to be used in an oil circuit recloser.



In sections up to ⅜", Y-2401 can be shaped by shaving dies as illustrated upper left.

(Center) Y-2401 drills cleanly, without chipping or cracking. Drill tools last longer without resharpening.

Here's the circuit breaker assembly with the Y-2401 parts in place. (Note how this assembly is composed almost entirely of various grades of versatile Phenolite.)

In test after test, this new high pressure laminate actually *created* new standards of performance. The illustration above shows how this new paper base-melamine Phenolite goes beyond current grades in arc resistance.

But that's only a start! Y-2401 does away with the difficult-to-machine aspects formerly encountered with melamine laminates. It can easily be punched, sawed, drilled, turned and milled to close tolerances. And being non-brittle, it can be rough-blanked much closer to final dimensions, thus reducing waste of stock and effecting lower machining costs.

Y-2401 has excellent dielectric strength, good moisture resistance and low dissipation factor. Combine all its good points, and you have the "just-right" insulation material for use in transformers, circuit breakers, switch bases, supports for sliding contacts; in radar, television and radio; in many other critical electrical applications. Available in 39" x 47" sheets, of thicknesses ranging from 1/32" to 1".

**DETAILED DATA YOURS FOR THE ASKING**—*Write for Technical Data Sheet on Phenolite Grade Y-2401. Contains complete listing of its properties and possibilities. Gives all other information for thorough evaluation. Address Dept. D-7.*

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## News Digest

titanium commercially feasible. The two other papers were "The Effect of Alloying Elements on Welds in Titanium," by G. E. Faulkner, Battelle Memorial Institute and "Surface Embrittlement of Titanium by Exposure of Weld Heat Affected Zone to Atmospheric Contamination," by C. E. Hartbower, D. M. Daley, Jr., and W. P. Hatch, Watertown Arsenal Laboratory.

A new device that combines the advantages of automatic welding with the visibility and flexibility of manual welding was described in a paper, "Improved Semi-Automatic Welding and Hard Facing," by H. S. Avery, T. G. Brashear, H. J. Chapin and G. H. Edmunds, American Brake Shoe Co. Electrode wire from coils is fed continuously, reaching the arc with a flux covering that serves the need for arc shielding, deoxidation, arc stabilization, slag coverage of the molten bead, and alloying if necessary. The range of filler metals is wide. Fluxes are being developed that will deposit mild steel of the E60 series type, higher yield strength build-up steels, martensitic steels for wear and impact resistance martensitic irons for abrasion resistance, and austenitic manganese steel with the same roll of electrode wire.

A new method of butt welding plates or pipes without the use of backing rings or bars was disclosed for the first time in the paper, "Consumable Insert Method of Root Pass Welding," by T. A. Risch and A. E. Dohna, Electric Boat Div., General Dynamics Corp. The method allows easier manipulation by the operator of an inert-gas-shielded tungsten arc torch to fuse completely to the parent metal a filler rod of controlled dimensions and composition which is inserted between the root faces of the butt joint. The joint preparation allows the use of pipe and tube manufactured to ASTM commercial tolerances of wall thickness and diameter.

A paper on "Inert-Gas-Shielded Tungsten-Arc Spot Welding" was given by C. A. McClean, Air Reduction Sales Co. This relatively new method provides the fabricator of light gage steels with a method of producing much the same type of joint as that obtained with instant spot welding without the need for a back-up as part of the welding tool and without forging pressure. The ability to work from one side only

# one stands out

## ...and REX is the standard by which all high speed steels are compared

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Crucible has been making REX® High Speed Steels for over half a century . . . and REX is still the standard of comparison wherever high speed steels are used. That's no idle claim . . . and you can prove REX's superiority for yourself by putting a piece to work in your own shop. You'll like its hardenability, response to heat treatment, and good tool performance.

Once you've tried it, we think you'll agree — *you can't find a high speed steel that will outperform REX.*


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## News Digest

broadens the scope of spot welding as a fabrication method. Spot welding of materials as thin as 0.025 in. without back-up or special jigging is possible, as well as the joining of dissimilar metals. The process is also considered as a secondary tool for tack welding prior to subsequent joining by other welding methods.

Sigma welding of carbon steels was reported on by J. R. Craig, Linde Air Products Co. His paper, "Shielded - Inert - Gas Metal Arc Welding of Carbon Steel," discussed typical, practical uses for sigma welding, including steel plate fabrication as well as casting repair. Process economies were presented, including costs of consumable materials, and operating (duty) factors obtainable on various types of jobs.

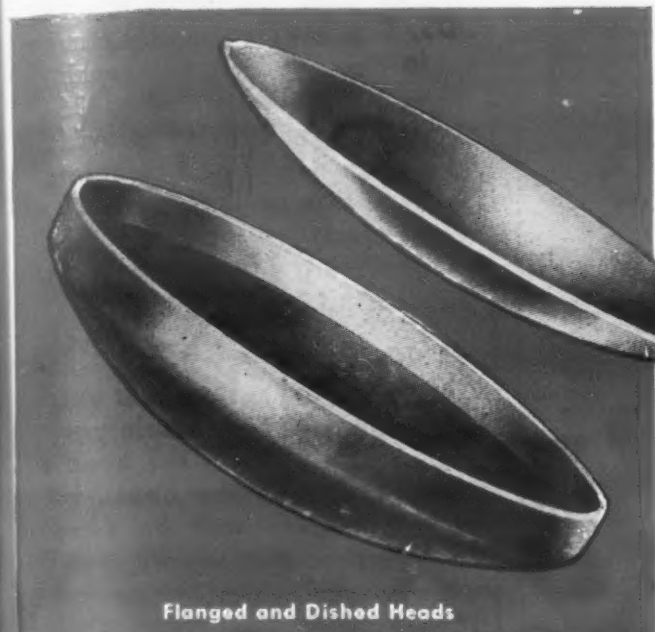
J. E. Hinkel, Lincoln Electric Co., in his paper "Powdered Metal Electrodes and Their Application," stated that both the users of welding and the manufacturers of welding equipment have reached a point in their knowledge of the arc welding process where it is now practical and economical to use electrodes for manual arc welding that have powdered metal in their coatings. These electrodes have advantages in speed of welding, smooth appearance, freedom from gouging and undercutting, excellent wash-in, easy slag removal and ease of operation. At present they are limited to downhand or nearly flat operation, although developments indicate that powdered metal coatings may be applied to out-of-position electrodes.

## Analyzes Steel Hydrogen Content

A thermal conductivity analysis system fast enough to determine the precise hydrogen content of steel during steelmaking is helping to speed research aimed toward elimination of hydrogen embrittlement. The new technique permits analysis of a sample of steel in about 15 min with a probable error of only plus or minus 0.12 parts per million of hydrogen.

Absorbed hydrogen, even when when present in such minute quantities as 3 parts per million, has a serious embrittling effect on steel without

# heads*---you win



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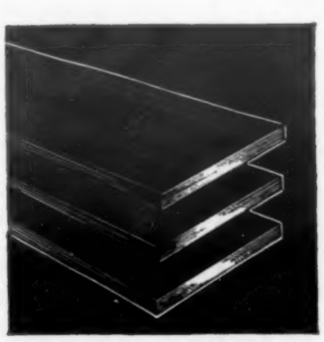
We can always meet your most exacting specifications because with us the spinning of flanged and dished heads is more than just a job—it's an art into which we put the most painstaking care and specialized know-how.

Our flanging department can supply you with flanged and dished heads in diameters from 9 inches to 19 feet and in gauges from 3/16-inch to 6 inches. Made in carbon steel, alloy steel or with stainless steel cladding. We are also prepared to handle head forming operations on both ferrous and non-ferrous metal circles supplied by the customer.

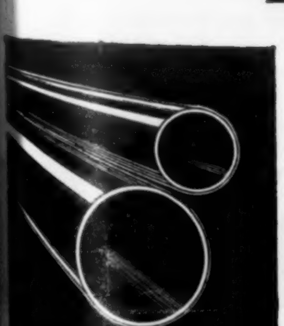
Other Claymont products include Stainless-Clad Steel Plates, Alloy and Carbon Steel Plates, Large Diameter Welded Steel Pipe.

Write or call Claymont Steel Products Department, Wickwire Spencer Steel Division, Claymont, Delaware.

Stainless-Clad Steel Plates



Alloy and Carbon Steel Plates



Large Diameter Welded Steel Pipe

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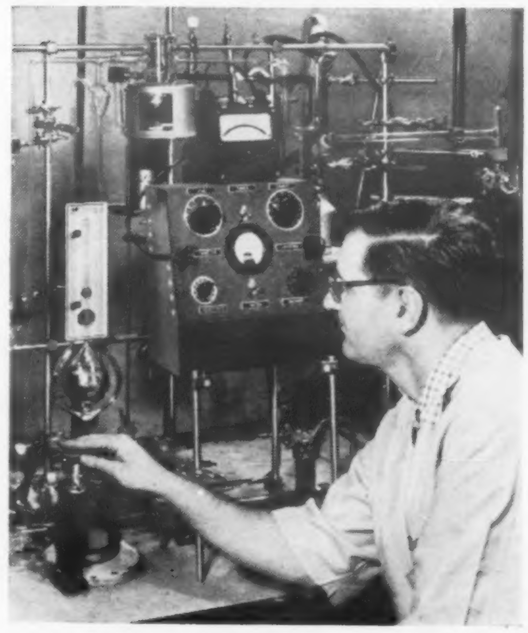

**Thermal conductivity** measurements permit rapid quantitative analysis of hydrogen content of steels.

a compensating increase in tensile strength. The new high-speed analytical equipment will permit a closer watch on steel melts in cases where it is vital to avoid the possibility of brittle fracture. The accuracy of the test is well within the boundaries required for analysis of hydrogen content.

The method of analysis for hydrogen is based on the vacuum tin fusion process developed by D. J. Carney, Chief Development Metallurgist of United States Steel's South Works, and J. Chipman and N. J. Grant of the faculty of Massachusetts Institute of Technology. The fusion process was recently modified by B. M. Shields of U. S. Steel, with cooperation of Professors Chipman and Grant, so that gases evolved from a steel sample can be analyzed for hydrogen in a thermal conductivity cell.

The improved method is applicable to the analysis of multicomponent mixtures when all gases in the mixture except one have nearly the same thermal conductivity. Fortunately, the mixture of hydrogen, nitrogen and carbon monoxide evolved by the tin-fusion analysis falls into this classification. The thermal conductivities of nitrogen and carbon monoxide are practically equal, while that of hydrogen is approximately seven times that of the other two gases. Thus, the thermal conductivity of the mixture at known temperature and pressure can be related directly to the percentage of hydrogen by suitable calibration.

The apparatus for detection and

# News Digest

measurement of hydrogen consists of a closed system of glass tubes with mercury cut-offs to control the gas flow, an induction furnace, two mercury diffusion pumps, a McLeod gage, a conductivity cell and a $1/2$-hp mechanical vacuum pump to extract air from the system. Measurements of conductivity are dependent on a precision ammeter with a range of 0 to 1.00 amp which, with the conductivity cell, is tied into an electrical thermal conductivity bridge activated by four $1\frac{1}{2}$-v dry cells.

A steel sample to be tested is placed in the evacuated induction furnace and is fused with pure tin. Mercury vapor in the diffusion pumps forces the gas from the furnace into a tube from which it escapes into a chamber of known volume. It is then conducted into a McLeod gage which records its pressure. To eliminate stratification, the gases pass through a mixing chamber before entering the thermal conductivity cell. A thin piece of pure platinum wire in the center of the cell is in a modified Wheatstone bridge circuit. The entire cell is maintained at 32 deg F by immersion in an ice and water bath.

The bridge circuit is balanced with the platinum wire held at a temperature of 77 deg F. The ammeter reading, indicating the amperes necessary to hold that temperature, is a measure of the thermal conductivity of the gas mixture in the cell. This reading is then compared to a calibration previously prepared by using gas mixtures containing various known percentages of hydrogen from 100% to 0% per cent. The comparison gives an accurate analysis of the hydrogen present in the mixture.

The over-all precision of analysis by the thermal conductivity method was evaluated by the use of duplicate samples. Each of 10 samples was cut in half to provide 10 sets of duplicates. A statistical study of the data obtained from these 10 pairs shows the standard deviation of the error of observation to be plus or minus 0.17 parts per million, with the probable error plus or minus 0.12 part per million. Using the statistical criterion of three standard deviations, a maximum error of 0.5 parts per million is possible, although the frequency of such an error will be extremely low.

*(More News on page 226)*

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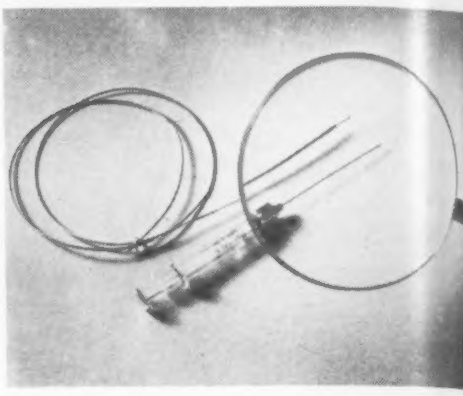

**Argonne thermocouple for measuring internal temperature of atomic reactor is only slightly larger than hypodermic needle.**

## Thermocouple for Atomic Reactors

A thermocouple which develops twice as much electromotive force as conventional thermocouples, yet utilizes the compact tube-and-wire fabrication technique is made of a constantan wire encased in an Inconel tube. Dr. W. Gerard Rauch of the Argonne National Laboratory developed the needle sized instrument. The first use of the thermocouple will be to measure the operating temperatures inside the fuel elements of nuclear reactor. For such use, a thermocouple must be very small in order not to absorb too much nuclear radiation and slow down the operation of the pile. It must also be corrosion resistant and capable of being threaded through winding passageways into the shielded elements of the reactor.

The Argonne thermocouple is only slightly thicker than the needle of a small hypodermic needle—0.040 in. Made in 20 ft lengths, insulated constantan wire is inserted in a small diameter Inconel tube, and the tube is then drawn through a die, which causes the outer tube to shrink around the inner tube, gripping it tightly. Fabrication is completed by fusing one end of the wire to form the thermocouple. The Inconel outside tube eliminates the need for a protective coating over the unit's 20 ft length. The thermocouples are extremely sensitive up to about 1250 F

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